

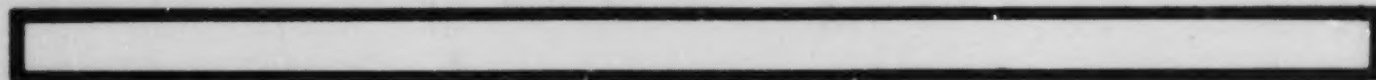
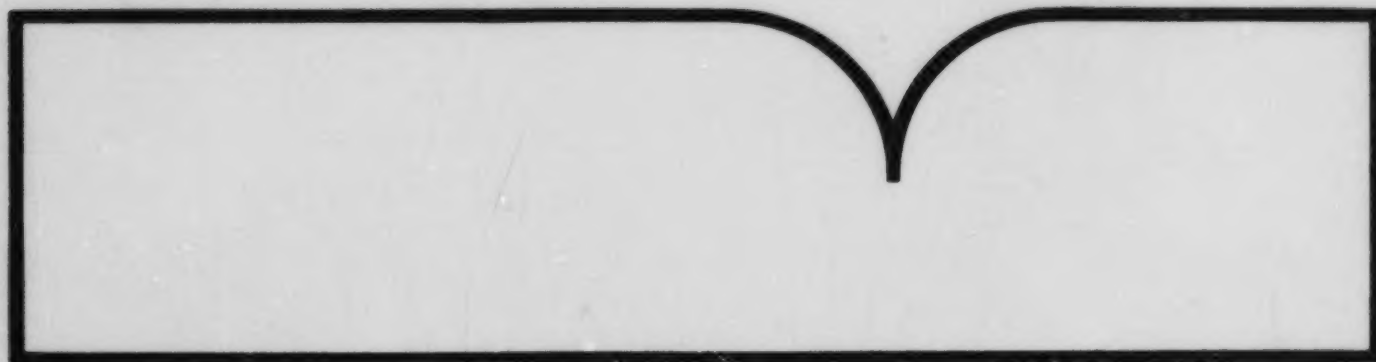
Retrospective Epidemiological Study of
Disease Associated with Wastewater Utilization

Hebrew Univ., Jerusalem (Israel)

Prepared for

Health Effects Research Lab.
Research Triangle Park, NC

May 84



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RETROSPECTIVE EPIDEMIOLOGICAL STUDY OF DISEASE ASSOCIATED
WITH WASTEWATER UTILIZATION

by

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16. ABSTRACT A retrospective epidemiological study was carried out on the association between enteric disease incidence and wastewater utilization in 79 kibbutzim (cooperative agricultural settlements) in Israel having a population of 32,672. Medical records on disease incidence were collected from patient files at each kibbutz clinic. Environmental data on location of sewage irrigated tracts, wind direction and source of water supply was collected for each kibbutz. The kibbutzim were divided into 4 categories: I) 30 irrigating with wastewater effluent in addition to freshwater; II) 28 not utilizing effluent for any purpose; III) 10 using wastewater effluent in fish ponds; IV) 11 which practiced 2 consecutive years of effluent utilization and another 2 consecutive years of effluent utilization and another 2 consecutive years in which no effluent was utilized for any purpose or vice versa. The high degree of intra- and inter-kibbutz variations of disease rate in the 68 kibbutzim in categories I-III resulted in conflicting findings and anomalies which did not provide a basis for drawing conclusions. However no evidence of excess risk associated with effluent irrigation was found. In the switch category (IV) a significant excess risk of total enteric disease ranging from 32-112 percent was found in the 0-4 age group during those periods in which wastewater was used for irrigation as compared to the non-wastewater irrigation periods, regardless of the direction of the switch. An excess risk of about 10 percent in effluent irrigating years was also found on an annual basis in each age group. None of the findings indicated that the main pathway of pathogen transmission was aerosolized effluent resulting from sprinkler irrigation.		
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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The complexities of environmental problems originate in the deep interdependent relationships between the various physical and biological segments of man's natural and social world. Solutions to these environmental problems require an integrated program of research and development using input from a number of disciplines. The Health Effects Research Laboratory, Research Triangle Park, NC and Cincinnati, OH, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. Wide ranges of pollutants known or suspected to cause health problems are studied. The research focuses on air pollutants, water pollutants, toxic substances, hazardous wastes, pesticides, and non-ionizing radiation. The laboratory participates in the development and revision of air and water quality criteria and health assessment documents on pollutants for which regulatory actions are being considered. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of environmental regulatory decisions involving the protection of the health and welfare of all U.S. inhabitants.

This report provides an evaluation of enteric disease and the use of wastewater for agriculture at 79 cooperative agriculture settlements in Israel. The reuse of wastewater has many beneficial effects provided it is done in a manner consistent with good public health and environmental practices. Epidemiological studies will provide a better understanding of whether or not health problems exist.

F. Gordon Hueter, Ph.D
Director
Health Effects Research Laboratory

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ABSTRACT

A retrospective* epidemiological study was carried out on the association between enteric disease incidence and wastewater utilization in agriculture in 79 kibbutzim (cooperative agricultural settlements) in Israel having a population of 32,672.

Medical records on disease incidence were collected directly from the patient's files at the clinic of each kibbutz. These records provided information on twenty-four defined diseases, laboratory confirmed or clinically diagnosed, half of which were enteric diseases which might possibly be transmitted by wastewater, while the other half were non-enteric diseases which served as controls.

Environmental data such as the location of the sewage irrigated tracts, wind direction and source of water supply was collected for each kibbutz.

- The kibbutzim included in the study were divided into four categories:
- I. Thirty kibbutzim irrigating with wastewater effluent in addition to irrigating with freshwater. Population: 13,531.
 - II. Twenty-eight kibbutzim not utilizing effluent for any purpose, which served as a control group. Population: 11,096.
 - III. Ten kibbutzim using wastewater effluent as feed-water for fish ponds. Population: 5,005.
 - IV. Eleven kibbutzim which practiced two consecutive years of effluent utilization and another two consecutive years in which no effluent was utilized for any purpose or vice versa. Population: 3,040.

The risk of enteric disease associated with various forms of effluent utilization was estimated for different age groups using both the logistic and log linear regression models which controlled for various confounding factors including: length of irrigation period, geographic region, source of water supply, source and volume of wastewater, source of clean irrigation water, population size.

No evidence of excess risk associated with effluent irrigation was found. However, the high degree of intra- and inter-kibbutz variation of disease rate in the analysis of the 68 kibbutzim in categories I-III resulted in conflicting findings and anomalies which did not provide a basis for drawing conclusions.

* Although some authorities prefer the name historical prospective for a study of this design, the term retrospective has been used for purposes of simplicity.

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The experimental design of the 11 kibbutzim in the "switch" category (IV) provided a sounder basis for obtaining unambiguous results. In the switch category a clearly significant excess risk of total enteric disease ranging from 32-112 percent was found only in the 0-4 age group during those periods in which wastewater was used for irrigation as compared to the non-wastewater irrigation periods, regardless of the direction of the switch. A small but significant excess risk of about 10 percent in effluent irrigating years was also found on an annual basis in each age group, as estimated by the log linear model only.

None of the findings provided direct support for the hypothesis that the main pathway of pathogens transmission was aerosolized effluent resulting from sprinkler irrigation.

Data from 68 kibbutzim, which were based on kibbutz clinic files, were compared with cases of salmonellosis, shigellosis and hepatitis reported to the Ministry of Health, and no serious discrepancy was found between the two sources. The present study did not confirm the extreme differences found in effluent irrigating kibbutzim in Katznelson et al.'s study (1976) for the kibbutzim included in this study, although a small significant excess risk of total enteric disease was found during effluent irrigation periods.

This study was carried out at the Environmental Health Laboratory of The School of Public Health and Community Medicine, Hebrew University - Hadassah Medical School, Jerusalem, Israel under U.S. Environmental Protection Agency Grant No. R-805174. The study was initiated in October 1977 and completed March 1, 1982.

Project Officer Comment - The main reason for support of this research was to follow up on the report in Science, 194 (1976) that there was a marked health hazard from wastewater spray irrigation. The authors could not confirm that earlier finding, and, in fact, discovered serious deficiencies in the data used in that study. They also imply that the data base provided by the kibbutzim is inadequate for a conclusive retrospective study and that caution should be exercised in interpreting the report due to the study's many methodological problems. Neither the numerator nor denominator could be reliably determined to calculate illness rates and ratios. A complex statistical analysis was necessary as an attempt to control for the inadequacies of the data as well as to adjust for differences in influential factors. A clear understanding of the methods used for data analysis is necessary in order to interpret the results and evaluate the findings of the study.

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SECTION 1

INTRODUCTION

Land application of wastewater serves both as an effective water pollution control measure and as a means of conserving water through recycling in areas suffering from shortages of water resources.

In the United States, the Environmental Protection Agency (EPA) has been assigned the task of evaluating the technological feasibility and potential health effects of land application of wastewater as a major water pollution control strategy. In Israel, wastewater reuse in agriculture is part of the national water resources management policy intended to help close the gap between the limited amounts of renewable fresh water resources and the growing water demand associated with increasing populations. This policy has resulted in the establishment of some 250 wastewater utilization projects, 90 percent of which practice sprinkler irrigation with oxidation pond effluent. By the year 2000, it has been estimated that Israel will be utilizing some 300-400 million cubic meters of effluent per year, primarily for agricultural purposes. The goal is that 80 percent of all municipal wastewater will be recycled in this manner.

The most prominent form of wastewater reuse in agriculture is by sprinkler irrigation. This results in the aerosolization of 0.1-1 percent of the effluent applied to the land. In the United States, sprinkler irrigation is also one of the most feasible modes of land application of wastewater.

There has been concern that the extensive use of sprinkler irrigation with effluent may present a potential health hazard for field workers and the population adjacent to the fields. Humans may be infected by aerosols containing pathogenic bacteria or viruses by inhalation of particles of 0.5-5.0 μm which can enter the respiratory system. The larger droplets, however, can be trapped in the upper respiratory system including the nose and larynx, and from there they may reach the digestive tract. Other modes of transport of pathogens from areas irrigated with wastewater are by direct contact with irrigation workers, contaminated crops and fomites.

Hickey and Reist, (1975) reported that pathogenic bacteria may be transported in aerosols from sewage to humans. In a later survey, (Clark et al., 1980) emphasized the potential risk to sewage workers of enteric diseases from occupational exposure. Adams and Spendlove, (1970) isolated microorganisms from aerosols at a distance of 1200m downwind from a sewage treatment plant. However, there is little evidence of the degree of health risk from aerosolized sewage.

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A recent review of health effect studies of wastewater aerosols is contained in the proceedings of the EPA Symposium on Wastewater Aerosols and Disease (Pahren and Jakubowski, 1980). The studies reviewed did not provide clear-cut evidence as to the health risks, if any, associated with wastewater treatment or reuse.

The Environmental Health Laboratory of the Hebrew University-Hadassah Medical School has succeeded in isolating coliforms at a distance of 350m, salmonella at a distance of 60m and enteroviruses at 100m downwind from the wastewater irrigated fields (Katzenelson and Teltsch, 1976; Teltsch and Katzenelson, 1978; Katzenelson et al., 1978).

One of the first retrospective epidemiological studies on the possible health risks associated with sprinkler irrigation of wastewater was carried out in Israel (Katzenelson, et al., 1976). In this study, the data suggested that in 77 kibbutzim (agricultural cooperative settlements) practicing mainly sprinkler irrigation with undisinfected oxidation pond effluent, the incidence of typhoid fever, salmonellosis, shigellosis and infectious hepatitis was two to four times higher than in 130 control kibbutzim not practicing any form of effluent irrigation. They concluded that these findings "provide some epidemiological evidence for increased risk of enteric communicable diseases" among users of partially treated, non-disinfected wastewater for irrigation.

The researchers themselves pointed out that from this study they could not provide definite proof that the suggested added health risk in effluent-utilizing kibbutzim was associated with the dispersion of pathogenic microorganisms by aerosols. This conclusion was drawn because a number of pathways of infection other than aerosols existed, such as direct personal contact via clothing or skin, of sewage irrigation and fish pond workers, or exposure to the crops, and fish grown in ponds using effluent.

This preliminary survey also had serious methodological constraints in that investigators based their findings solely on official communicable disease reports which were submitted to the Ministry of Health as required by law. These requirements do not include the listing of all relevant diseases, indicating serious reporting deficiencies. The comprehensiveness of kibbutz reporting to the Ministry of Health is not known. Other methodological deficiencies existed also.

For example, the irrigation period, as defined in that study, was arbitrarily set as April to November, rather than the actual irrigation period which varies from 3 to 12 months per year. The effluent irrigation status of the kibbutzim were determined according to the Ministry of Agriculture report of 1975 and assumed that the status was correct for the entire study period, while the disease data covered a period of from 2 to 13 years. In a check of the Ministry of Agriculture reports for available years 1971, 1975 and 1978 (Water Commissioner, 1971, 1975, 1978), it was found, for example, that in the above-mentioned seven-year reporting period, there was an increase of about 35 percent in the number of kibbutzim irrigating with wastewater, while about 10 percent of the kibbutzim ceased wastewater irrigation. Thus about 45 percent of kibbutzim changed their wastewater

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irrigation status during the study period. Detailed data on the changes in category during the 13 years of the study are not available, but it can be assumed from the available data that a similar trend of changes in status may have occurred.

In addition, a field check on the accuracy of the Ministry of Agriculture reports on wastewater irrigation status indicated that some 16 percent were incorrectly categorized. Moreover, in that study, communicable disease data for different diseases was based on varying periods of time--from two years for influenza, up to 13 years for typhoid fever--leading to difficulties in interpreting the epidemiological implications due to such factors as disease cycles and epidemic periods. For the above reasons, conclusive findings should not be based on that study.

The World Bank monograph on appropriate technology for water supply and sanitation (Kalbermatten, et al., 1980) states that the "Data on the health effects of night soil or sewage upon sanitation or agricultural workers are inconclusive, although the risk is self-evident." This statement illustrates the ambiguous situation that exists in this area and which may lead to overly restrictive policies concerning wastewater reuse - especially in those areas suffering from water shortages. What are required are carefully designed studies which can provide accurate data to assess the real nature of the risks involved in sewage reuse and can serve as a basis for developing a sound public health policy.

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In light of all the above problems, new research based on primary medical and environmental data collected at each kibbutz was carried out by this project to confirm or rebut the findings of the initial retrospective study of wastewater irrigation in kibbutzim.

The present report covers a study of the health records during the years 1974-77. These are taken directly from the clinic files of 32,672 persons in 79 kibbutzim in the following categories:

- I. Kibbutzim practicing sprinkler irrigation with wastewater and exposed to wastewater aerosols.
- II. Kibbutzim not exposed to wastewater aerosols, nor practicing any form of wastewater irrigation or utilization. This category served as the control group for categories I and III.
- III. Kibbutzim not exposed to wastewater aerosols but utilizing wastewater as feed water for fish ponds.
- IV. Kibbutzim that switched from non-wastewater use to wastewater use or vice versa, thus serving as controls for themselves.

In most cases, the method of wastewater treatment prior to utilization was oxidation ponds, with 5-10 day detention periods (Noy and Feinmesser, 1977). Coliform concentrations in effluent were very high and usually ranged from 10^6 - $7/100$ ml while enteric virus concentrations in effluent ranged from 10^2 - 10^3 PFU/100 ml (Zahavi, 1976). High concentrations of

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Salmonella organisms are commonly detected in municipal wastewater in Israel (Yoshpe-Purer and Shuval, 1972). These concentrations of enteric micro-organisms were considerably higher than those at comparable land application sites in the United States.

Thus this project in Israel represents what may be considered a "worst case" of population exposure to wastewater land application practice in general, and aerosolized pathogens of sewage origin in particular. If little or no health risks can be detected under such extreme conditions of environmental exposure to pathogens, the risk associated with land application projects using significantly higher quality effluent may be negligible or nonexistent. If, however, some health risks are detected under the extreme conditions of this study, it will provide some indication of the type and degree of additional prophylactic measures which should be introduced to prevent or reduce the risks to an acceptable level.

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SECTION 2

CONCLUSIONS

1. Based on simplified analyses, no excess of total enteric disease was observed in effluent irrigating (category I) kibbutzim (collective agricultural settlements) over non-effluent utilizing kibbutzim (category II) during the irrigation period or on an annual basis. An excess was observed in total enteric disease rates in kibbutzim utilizing effluent as feed water for fishponds (category III) over both categories I and II during the irrigation period and on an annual basis. Due to the numerous and complex confounding factors not controlled for in a simple comparison of crude rates, no attempt at drawing conclusions from these observations was made.

It was concluded that a regression type analysis by the logistic and log linear models was required to control for confounding factors so as to estimate the risk of enteric disease, if any, associated with the various wastewater utilization practices in the kibbutzim included in this study.

2. Not all distributional assumptions which underlie both the logistic and log linear models could be examined by the data. Those that were examined were found to be reasonably satisfied.

The log linear model succeeded in explaining about 50 percent of the intra- and inter-kibbutz variation of the enteric disease rates ($R^2 = .50$) based on episodes culled from kibbutz clinic files.

However, much of this apparently good fit is due to an artifact associated with the high correlation between enteric and control diseases, which might reflect differences in quality of reporting in the kibbutzim. Thus the fit, due to the main variables under study, is considerably less. The fit for the logistic model was about the same as that of the log linear, after considering the effect of the quality of the reporting.

The above conclusions concerning the basic assumptions and fit of the two models apply to the analysis of the risk of enteric disease for the 68 kibbutzim in which a comparison was made between 30 effluent irrigation kibbutzim (category I) as against the 28 control kibbutzim, in which only non-effluent was used for irrigation (category II) and the 10 kibbutzim using effluent as feed water for fish ponds (category III).

The two models showed a far better fit for the data in the switch category (IV) design (11 kibbutzim that irrigated two years with non-effluent and switched to two years of effluent irrigation or vice versa). The coefficient of determination for the fit of the log linear model was

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very high ($R^2 = .94$), with an equivalently good fit for the logistic model.

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It was concluded that, despite the numerous co-variates entered into both models for the analysis of effluent vs. non-effluent utilization categories (the 68 kibbutzim), insufficient control of inter-kibbutz variations was obtained.

On the other hand, these very same kibbutz-specific confounding factors were almost completely controlled for in the switch category. This was due to its block type design with each community serving as its own control. Thus, the switch category provided a far superior design on which the conclusions of this study are mainly based.

3. Both the logistic and log linear models used to estimate the risk of becoming ill with any of the 12 enteric diseases (total enteric) in association with various wastewater utilization practices in the study of the 68 kibbutzim in categories I-III produced results which were often highly conflicting and fraught with anomalies, to the extent that it was not possible to draw clear and significant conclusions from most portions of the analysis of the data set. However, on an annual basis it could not be concluded from the study of the 68 kibbutzim that there was evidence of an excess risk of enteric disease in effluent irrigating kibbutzim (category I) over non-effluent irrigating kibbutzim (category II).

The results did suggest that there might be an excess risk of enteric disease in effluent irrigating kibbutzim (category I) over non-effluent irrigating kibbutzim (category II) during the "period of exposure" to effluent (i.e., the actual months of irrigation as recorded for each individual kibbutz) with a deficit during the non-irrigation period, and no excess risk at all on an annual basis. There was also evidence pointing to an excess risk of enteric disease in both seasons and on an annual basis in kibbutzim utilizing effluent as feed water for fish ponds (category III) over category II.

Caution should be used in evaluating these possible trends, particularly in relation to fish ponds, since this study did not include a control group of non-effluent utilizing fish ponds.

4. Within category I, no correlation was found between crude enteric disease rates and the aerosol exposure index used, which included the following parameters: distance; wind direction and velocity; size of effluent irrigated field; and length of irrigation period.

5. The results of the study for the 68 kibbutzim, based on crude rates of specific diseases (shigellosis, salmonellosis and infectious hepatitis) culled from both the kibbutz clinic files and from the Ministry of Health records of reported cases of communicable disease, did not confirm the findings of the Katzenelson et al., (1976) study, which indicated an excess of 2.0-4.3 times for the above specific enteric diseases in effluent irrigating vs. non-effluent irrigating kibbutzim. Based on kibbutz clinic files, the shigellosis rates were found to be about 26 percent greater in effluent irrigation kibbutzim during the irrigation season as compared to

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non-effluent irrigating kibbutzim, but no excess for salmonellosis or infectious hepatitis was found, nor was there any excess risk of total enteric disease on an annual basis.

6. In the switch category (IV), the analysis by both the logistic and log linear models showed a significant increase in risk of enteric disease in the irrigation period during the effluent irrigating years over the non-effluent irrigating years for the 0-4 age group, regardless of whether the switch was from non-effluent to effluent or vice versa. The estimated excess in enteric disease ranged from 70 percent to 112 percent by the odds ratio (O.R.) as estimated by the logistic model and was about 30 percent according to the relative risk (R.R.) as estimated by the log linear model.

There was also a significant excess risk of enteric disease in the other age groups during effluent irrigation periods, however, without the same degree of uniformity as found in 0-4. The estimated excess ranged from 7-25 percent by O.R. and R.R.

On an annual basis there was a significant excess risk of about 10 percent in each age group separately and all ages by the log linear model, which was not found in the analysis by the logistic model. The findings by the logistic model analysis do not necessarily negate those of the log linear model. Thus, it was concluded that a small but significant excess risk of enteric disease on an annual basis did exist during the effluent irrigation years in the switch category.

The finding of a significant excess risk of enteric disease in the irrigation season during the effluent irrigation years before the switch to non-effluent irrigation supports the suggestion that the risk associated with exposure to effluent is long term and not only associated with the introduction of wastewater irrigation into a previously unexposed community.

7. The findings in the switch category of an excess risk of enteric disease during the effluent irrigation months, but with little or no excess on an annual basis, can be explained, in part, by the results of the analysis of the annual cycles of crude enteric disease rates in the study of the 68 kibbutzim.

The monthly crude rates for effluent irrigating kibbutzim (category I) were observed to increase rapidly shortly after initiation of irrigation. Monthly enteric disease rates for May-July were higher in I compared to II, dropping to a lower level for most of the remaining months of the year. This held for 0-4 and all ages. The annual crude rate of enteric disease in both I and II were the same. The control diseases showed the known inverse cyclical pattern peaking in December and January, with lows during the summer months. No differences in the annual cycle for control diseases between I and II were observed.

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The annual cycle of enteric disease suggests that, in category I, there may indeed be increased transmission of enteric disease on the initiation of wastewater irrigation in the spring, but that, in the unique kibbutz situation with intimate communal living including a common dining hall, there are

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continuous multiple exposures to enteric pathogens, which result in a certain annual saturation level of enteric disease, regardless of wastewater utilization practices.

The annual appearance of lower enteric disease rates late in the irrigation period and after it, during the winter in category I as compared with category II, suggests that some form of short term immunity may have developed in a portion of the exposed population.

8. Despite the evidence that there was an excess risk of total enteric disease in kibbutzim during the period of exposure to effluent (i.e., the effluent irrigation period), the annual excess risk for all ages was nil or quite small, thus indicating that the overall risk of enteric disease resulting from effluent irrigation in kibbutzim in Israel is not a public health problem in general, but might become one during epidemic periods. Many of these findings are related to the unique kibbutz lifestyle. Whether or not a similar degree of exposure of typical U.S. families in private homes in a non-communal situation, to enteric disease pathogens associated with wastewater effluent irrigation of similar quality would result in an excess risk of enteric disease on a seasonal or an annual basis cannot be determined from this study.

9. Extrapolation of these findings to situations of wastewater utilization in agriculture and/or land application in the United States must take into consideration the fact that, in general, the effluent used for irrigation at kibbutzim in Israel was only minimally treated in oxidation ponds with detention periods of 5-10 days. It was generally of poor microbial quality, having coliform concentrations of about 10⁶/100 ml and enteric virus concentrations ranging from 10²-10³ PFU/100 ml. Whether or not the same degree of risk of enteric disease associated with wastewater utilization found in this study would exist if better treated effluents, typical of those from conventional biological treatment plants or their equivalent, had been used was not evaluated.

10. Caution must be used in the interpretation and application of all of the above conclusions in light of the many methodological problems associated with this retrospective study.

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SECTION 3

RECOMMENDATIONS

1. In light of the finding that a significant risk of enteric disease during irrigation periods was associated with irrigation with effluent from short detention period oxidation ponds having low efficiency in the removal of enteric microorganisms in kibbutzim in Israel, it is recommended that a higher degree of effluent treatment be provided as a prudent public health measure. Even though the excess risk on an annual basis is nil or small, the higher level of treatment can be justified as a safety factor particularly to reduce possible increased disease transmission during epidemic periods.

2. Despite the numerous methodological problems revealed in estimating the risk of enteric disease associated with the use of similar quality effluent as feed water in fish ponds, the evidence points to the presence of an excess risk in this group of kibbutzim in Israel, which justifies taking precautionary measures. It is recommended that a higher level of treatment, assuring more efficient removal of enteric microorganisms, be provided prior to discharge of effluent to fish ponds or that effluent use be avoided.

3. In Israel and other countries suffering from serious water shortages, where effluent reuse and/or land application has become a matter of national water planning policy, society should provide long term health monitoring programs to achieve an unambiguous evaluation of the risk to the public and to determine the type of preventative action required where significant excess risk is revealed. This applies in particular to areas where previously unexposed populations will be involved in effluent irrigation and/or land application programs for the first time.

4. Due to the serious methodological problems revealed in this retrospective study, it is recommended that the prospective investigations be conducted to gather more conclusive data concerning potential health risks associated with land application of wastewater.

5. It is recommended that special emphasis be given to improving the comprehensiveness and consistency of medical recording and that all sources be utilized, including the nurses' and doctors' daily logs. Investigation of outbreaks and special studies on the highly susceptible groups of volunteers should be included. Of critical importance is the sampling of blood and stools in children, effluent workers and volunteers so as to determine infectivity rates and immunity in relation to effluent exposure. These cannot be readily detected by recording cases of clinical disease.

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6. Further research should study the apparent association between effluent utilization and the excess of control diseases such as streptococcal throat infections observed in this study.

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SECTION 4

RESEARCH DESIGN AND PROCEDURES

THE KIBBUTZ SETTING

Kibbutzim Selected for Study

Out of 224 kibbutzim in Israel with a total population of 93,000, 79 having a total population of 32,672 were selected for the study. The kibbutzim were placed into four categories:

- I. Thirty kibbutzim utilizing both their own sewage effluent and/or that of nearby urban settlements for irrigation. These kibbutzim also used non-effluent water for irrigation. They are assumed to be either exposed to aerosolized sewage and/or to other pathways of transmission, such as food and body contacts or transmission by fomites, and do not have fish ponds. The population of this group is 13,531.
- II. Twenty-eight kibbutzim not practicing irrigation with sewage effluent (but utilizing other sources of water) and not exposed to aerosolized sewage from effluent-irrigated neighboring fields within 5 km. from the residential area. They do not have fish ponds. This group has a population of 11,096. This category served as the control group for I and III.
- III. Ten kibbutzim utilizing their own sewage effluent and/or that of adjacent settlements for enrichment of their fish ponds to grow fish for human consumption. Some of these kibbutzim use the fish pond water after drainage for crop irrigation. These kibbutzim are not exposed to aerosolized wastewater and have a population of 5,005.
- IV. Eleven kibbutzim were in a switch category and practiced two consecutive years of irrigation during which effluent sources were used for at least part of the year followed by another two consecutive years in which only non-effluent water sources were used for irrigation or vice versa. The population of this group was 3,040. This category was used at first as a pilot study to test the methods of analysis and some changes were made as a result of the pilot experience.

In selecting kibbutzim for the study, the following criteria were used: geographical distribution; proximity to meteorological stations; varied sources of effluent; distribution among the various kibbutz movements; founded 1960 or earlier; minimum population of at least 200 and maximum population of about 1,000. Thus about 50 percent of the potential candidates for categories I and II were selected. For categories III and IV,

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essentially all available candidates were used. Due to shortages of water, fish ponds are not used by settlements in the central and southern regions of the country. Thus category III kibbutzim were located mainly in the northern region.

Figure 1 shows the geographic distribution of kibbutzim in the study, according to category. The study covered the four-year period of 1974-77 for the 68 kibbutzim in categories I-III, while in category IV, the study encompassed two consecutive years of effluent irrigation followed by two years of non-effluent irrigation in six kibbutzim, while the reverse was true for five kibbutzim. The switch category (IV) study period spanned the years 1963-1977.

Extent of Exposure to Wastewater Pathogens

It has been assumed that the population of kibbutzim in category I were exposed to both aerosolized pathogens in wastewater effluent and/or direct or indirect contact with wastewater pathogens by contact with irrigation workers, fomites or food. It was further assumed that the population in category III kibbutzim were not exposed to aerosolized pathogens from effluent, but were exposed to wastewater pathogens by contact, fomites or food. The population in category II was assumed not to have been exposed to wastewater pathogens in any manner.

In Israel, most wastewater irrigation takes place during the seven dry summer months (April-October) with a five-month period in the winter (November-March) of no irrigation. However, there was considerable variation among the kibbutzim included in the study. Irrigation periods ranged from 3 months to 12 months and the month during which irrigation began varied from March through June. There was no exposure to wastewater pathogens in category I during non-irrigation months. It should be noted that effluent was used for feed water in fish ponds all year round, thus potential exposure to pathogens from contact with wastewater did not cease completely in the winter or non-irrigation season for kibbutzim in category III.

An additional variable built into the study design was associated with the source of the wastewater used for irrigation. While 18 effluent irrigating kibbutzim in category I used only the effluent of the kibbutz itself, 12 kibbutzim used effluent from a neighboring community alone or in combination with effluent from the kibbutz itself.

Working Hypothesis

This study has been designed to test the working hypothesis that there is an increased risk of enteric disease associated with exposure to pathogens in aerosolized wastewater of the particular quality used in the study kibbutzim and/or by direct contact with effluent workers, effluent contaminated fomites, food and crops. If this is true then:

1. Category I will show higher enteric disease rates during irrigation periods than category II, while rates in non-irrigation periods should be similar, thus leading to an excess in I over II on an annual basis.

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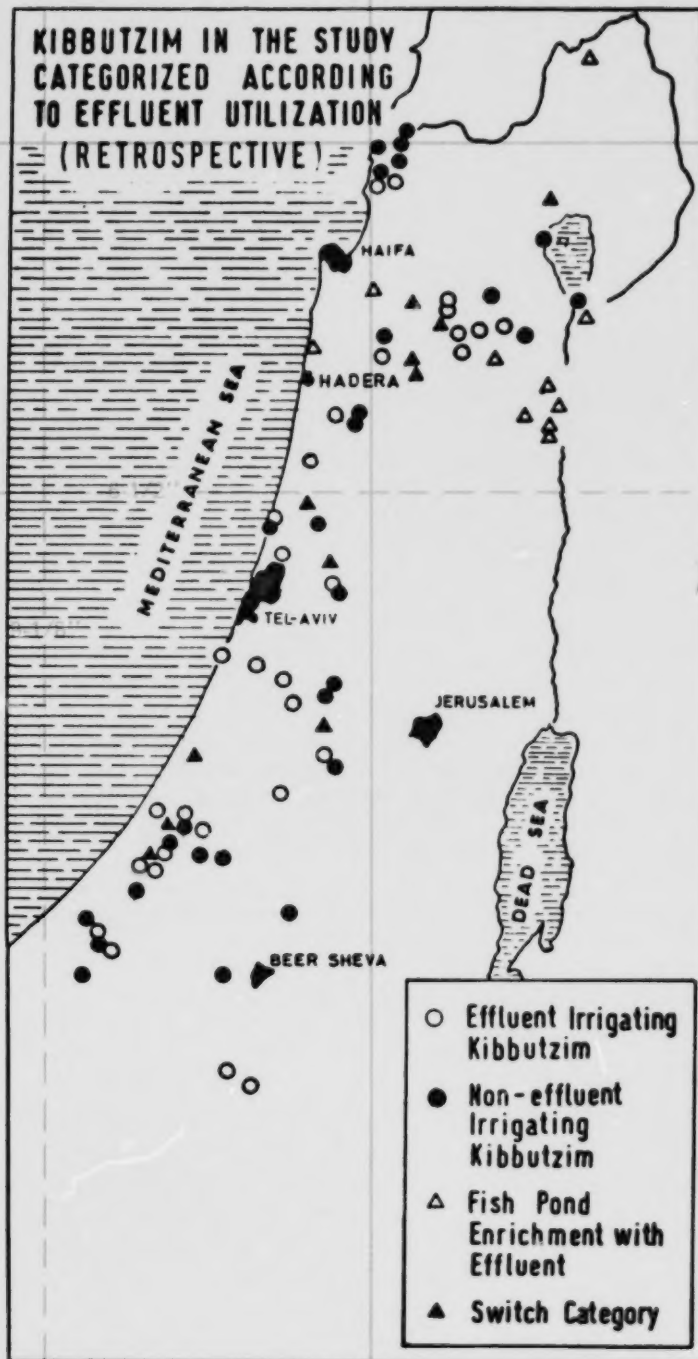
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Figure 1. Geographic distribution of kibbutzim by category.

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2. Category I will also show higher enteric disease rates than category III due to the additional risk associated with aerosol and wastewater.
3. Category III will be equal to or higher than category II.
4. There will be no differences in the control disease rates in I, II and III since they are assumed not to be associated in any way with contact with wastewater.
5. Within category I, enteric disease rates will be higher as the extent of exposure to aerosolized wastewater increases, i.e., as the distance between the residential area and nearest effluent irrigated fields decreases; as the residential areas are predominantly downwind from effluent irrigated fields; as the size of the effluent irrigated field increases and as the volume of the effluent utilized increases.
6. Within category I, enteric disease rates will be higher in kibbutzim utilizing the effluent of neighboring communities over those utilizing their own effluent. This is based on assumption of higher immunity levels within a community to endemic diseases as compared to the pathogens in the wastewater from neighboring communities.

The Advantages of the Kibbutz for Testing the Working Hypothesis

There are many kibbutzim using sprinkler irrigation in which the main sewage treatment is non-disinfected oxidation ponds. In contrast, there are other kibbutzim which neither use effluent for irrigation nor sewage for fish ponds. In each kibbutz there is a clinic staffed with a nurse and serviced by a physician. In addition, there are regional laboratories which perform routine communicable disease examinations for the kibbutzim.

The kibbutz in Israel provided a good study situation which allowed us to thoroughly investigate the preceding hypothesis. The socio-economic and educational level of the population in all the kibbutzim is more or less the same. Thus these factors did not play a significant role in the study.

Another advantage of the kibbutz as a study situation was the high level of consciousness of the kibbutzim in health matters, as well as their capability to record the environmental and medical data and their general willingness to cooperate with a research effort of this kind.

While clinical data recording in kibbutzim is generally more comprehensive than that of urban clinics in Israel, there was considerable variation in record-keeping practices of the kibbutzim which must be considered in the data analysis.

SOURCES AND QUALITY OF DATA

Basis for Determining Kibbutz Population and Age Distribution

Two potential sources of information were available for establishing kibbutz population and age distribution. The first was the census of the

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kibbutz population as recorded by the kibbutz itself or by various kibbutz movements' central organizations that compile kibbutz statistics. The second source was based on the clinic files for each person whose health data was recorded in this study. Each file contained the date of birth of the member and was started shortly after arrival for each resident of the kibbutz, regardless of status. The study design recorded the relevant data from every file in the kibbutz clinic regardless of the type of illness or whether the person made any visits to the clinic during the four-year study period. Thus the use of the clinic files for determining the population and age distribution was considered a promising potential instrument if problems arose from the census.

On further investigation, it was revealed that the various kibbutz movements used different methods for carrying out their censuses (such as different age category groupings) and complete data for all kibbutzim was not available. In addition, the year of the census varied and each movement had different definitions of membership status, candidates, etc. A check of the reliability of the census data in a number of kibbutzim indicated serious discrepancies between the published census figures and the number of patients actually being handled in the kibbutz clinics. All of these factors led to a lack of comparability, making the census data extremely difficult to analyse in a meaningful manner. After considering these inadequacies, the use of the clinic files as a basis for determining population and age distribution remained the only viable choice. The inadequacies of this source must be recognized, since it was revealed that patients' clinic files were not always closed when residents left the kibbutz. The extent of this problem could not be determined. The clinic files were generally reliable in the critical groups of infants and children, since files on infants are opened at birth.

Since it was not feasible to accurately calculate a different population base for each year of the study, it was decided to establish the total population and age distribution according to the clinic files as of January 1, 1976. This date was midway in the study period for the 68 kibbutzim in categories I-III. In the switch category, the population was established at the midway point, i.e., during the year the kibbutz switched its effluent irrigation practice. Population shifts during the four-year study period were generally not greater than 1-3 percent per year. The largest variation was 7 percent.

The total population for the 68 kibbutzim in categories I-III as calculated from the clinic files, was 29,632. Of these, 13,531 were in category I; 11,096 in category II; and 5,005 in category III. Category IV had a population of 3,040. The total population studied (based on clinic files) was 32,672.

Personal Medical Records

The data were culled from these records for the period January 1, 1974 to December 31, 1977 in the 68 kibbutzim of categories I-III. In the switch category, data were collected during 1963-1977; in each case a four-year run

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of two consecutive years of effluent irrigation followed by two consecutive years of non-effluent irrigation or vice versa was used.

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Of the 24 diseases chosen, about half were diseases which could be wastewater-borne (called enteric, in brief) and the other half were diseases assumed to be not generally associated with wastewater (called control, in brief), (Benenson, 1975) (see Table 1). Table 2 presents a group of selected enteric diseases with a high percentage of laboratory confirmed diagnoses, as well as a selected control group 1 that has also been chosen, which includes primarily respiratory infections, and a selected control group 2. It is recognized that certain of the disease conditions such as upper respiratory infections, included in the list of control diseases, could possibly be caused by enteric viruses of wastewater origin. It has been assumed that such possibly wastewater-associated etiological agents are not the predominant cause of upper respiratory infections and that, in general, the control disease rates are not influenced by the environmental exposure to wastewater. However, the fact that the control diseases may be influenced by spurious factors cannot be overlooked in the analysis.

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TABLE 1. LIST OF DISEASES RECORDED FROM PATIENT CLINIC
FILES IN THE STUDY KIBBUTZIM

Potential Wastewater Borne Diseases ENTERIC	Non-Wastewater Diseases CONTROL	Others*
Typhoid Fever	Upper Respiratory Infections	Influenza
Paratyphoid	Throat Infections**	Bacterial Food
Salmonellosis	Measles	Poisoning
Shigellosis-Bacillary Dysentery	Chickenpox	
Gastro-Enteritis	Accidents	
Aseptic Meningitis	Rubella	
Infectious Hepatitis	Mumps	
Fever of Unknown Origin	Pneumonia*	
Coxsackie Virus Infections	Bronchitis*	
Parasitic Infections*	Urinary Tract Infections	
Amebiasis*		
Leptospirosis*		

* Not included in the switch category.

** In the logistic and log linear model, only laboratory-confirmed streptococcal throat infections were included.

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Influenza was removed from the list of control diseases for the above reason and analysed separately. Bacterial food poisoning was also analysed separately since it was felt to be inadvisable to establish in advance whether it should be considered together with the other enteric diseases or with the control diseases.

In addition to these aforementioned groupings, the study was designed to allow for the analysis of each of the 24 diseases independently. In the analysis of the switch category (IV), the following diseases were not included: parasitic infections; amebiasis; leptospirosis; pneumonia; and bronchitis. The analysis of the switch category was designed as a pilot study and only on its completion was it decided to add the above three enteric and two control diseases.

Selected control disease 2 (Table 2) includes disease conditions such as accidents and mumps which could not in any way be associated with an etiology of wastewater origin. Since the total number of episodes of such diseases was small, their usefulness in the analysis was limited.

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TABLE 2. SELECTED ENTERIC AND SELECTED CONTROL DISEASES

Selected Enteric	Selected Control 1	Selected Control 2
Typhoid Fever	Upper Respiratory Infections	Measles
Paratyphoid	Influenza	Chickenpox
Salmonellosis	Pneumonia	Accidents
Shigellosis-Bacillary	Bronchitis	Rubella
Dysentery		Mumps
Parasitic Infections		
Amebiasis		

Medical data was collected from clinic files available for all the residents of the kibbutz including members, candidates, children, students in the newcomers training centers, temporary residents and volunteers. In general there was a clinic file for each kibbutz resident. In some cases, however, files for individuals who left the kibbutz may have been held in the clinic for extended periods, while files of temporary residents, students and volunteers were not consistently held after their departure. The extent of such deviations could not be evaluated. There is no reason to assume that there were any differences among the kibbutz categories in this matter.

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The data included: sex; date of birth; year when he/she first visited the medical clinic; total number of clinic visits during the study period,

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type of resident (member, etc.), day of the clinic visit, when illness began, and number of illnesses. Personal data was also collected for members who were not sick during the course of the study. The medical data collection form is shown in Figure A-1.

The quality of the medical data posed a problem in that serviceability of recording (comprehensiveness, consistency and continuity of medical data recording) was not uniform in all the kibbutzim. This included the records of nurses, who play a decisive role in the clinic system in the kibbutz and those of physicians who usually visit the kibbutz twice weekly.

In the course of ongoing work, which started after the conclusion of the field stage of this study, it had become apparent that many visits to the kibbutz clinic, home visits or other informal contacts with clinic staff outside the clinic, either go unrecorded or are recorded in the nurse's daily log, but not transferred to the patient's clinic file. The clinic patient file served as the sole source of data in this study. The mean number of recorded clinic visits/person/year for all symptoms and diseases was 3.3 (see Figure 9), while reports from the Kupat Holim General Sick Fund indicate that the national mean number of general practice clinic visits for all causes was about twice as large (Weitzman et al., 1981).

The lower level of recorded visits to the kibbutz clinic is undoubtedly associated at least in part with the unique nature of kibbutz clinic practice in which nurses routinely provide many forms of primary medical care normally handled by physicians in the city. Since most of such contacts are not recorded in the patient clinic file, it was anticipated to find a lower rate of recorded clinic visits in kibbutzim.

It was further discovered that morbidity data for volunteers and temporary residents was not routinely recorded by the clinics. Files of transients were usually not kept after their departure. Thus, medical records for the period of their residence were often not available. This group was very critical to this type of study due to their probable high susceptibility to diseases related to effluent exposure. It is our feeling that such groups of previously unexposed people are the most vulnerable to change in health status and could provide critical information concerning the degree of risk associated with wastewater irrigation during short periods of exposure.

Another difficulty which this study could not overcome was the problem of outbreaks. In the course of conducting a prospective study, it became clear that vital information on outbreaks was not routinely recorded in the patients' clinic files since the clinic staff in many kibbutzim was unable to deal both with the increased workload resulting from the outbreak and the recording of morbidity data during these periods.

Environmental Data

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Environmental data was obtained for the kibbutzim in the study through the agricultural manager of each kibbutz. Interviews were conducted once during the field work stage of the study to obtain data such as: use of

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effluent, volume of effluent used and treatment of same, methods of irrigation, the size of the sewage-irrigated tract and type of crops, and the distance of the tracts from the communal dining halls. Only kibbutzim which had no significant changes in wastewater utilization status during the whole study period and fit the categories as defined were maintained for the study. Those which changed their status of wastewater use, had good reporting and suitable data were included in the switch category.

The data was coded on special coding forms and punched onto computer cards. There were four cards containing environmental data for each kibbutz. After punching, logical tests were performed. The questionnaire used for interviewing is as shown in Figure A-2.

The quality of the environmental data collected by interviews in 1978 and 1979 might be affected by the fact that the information gathered went back over a four-year period for kibbutz categories I-III and as much as 13 years for category IV -- the switch category. In general, reliable information was provided by farm managers, irrigation branch managers and fish pond managers, who were themselves in charge of the operation for all or most of the period reported upon. In a few cases, younger managers provided information based on files or on information provided by retired personnel. Where it was felt that dependable environmental data was not available, especially in regard to wastewater utilization practices and month of irrigation, the kibbutz was dropped from the study. Nevertheless, it must be recognized that some of the environmental data was based on recall rather than written records, so that it was assumed that certain inaccuracies were recorded.

Meteorological Data

Meteorological data was recorded from the nearest Meteorological Service weather station. Figure 2 shows the geographic distribution of effluent irrigating kibbutzim (I) and the location of the 13 meteorological stations from which data was recorded. In most cases, the distance between the meteorological station and the kibbutz for which the data was applied was less than 10 km. In a few cases, the distance reached 15 km. Meteorological data included a minimum of twice-daily records (day and night) of wind direction, wind speed, temperature and relative humidity. Means and frequency distribution for the four-year study period were recorded.

The meteorological data was drawn from 13 Government Meteorological Service stations in the immediate proximity of the kibbutzim included in the study (Manes et al., 1980). The data is of good quality, of a high level of accuracy and carefully monitored by the Meteorological Service. However, since distances between stations and the kibbutzim varied from a few km. to 15 km., it must be assumed that a certain degree of error in wind direction and wind speed resulted when data from the nearest station was used to determine the exposure of kibbutz residents to aerosols from adjacent wastewater irrigated fields. Local topographical factors may have had a significant effect which could not be taken into consideration in the analysis and may lead to errors, the extent of which cannot be determined.

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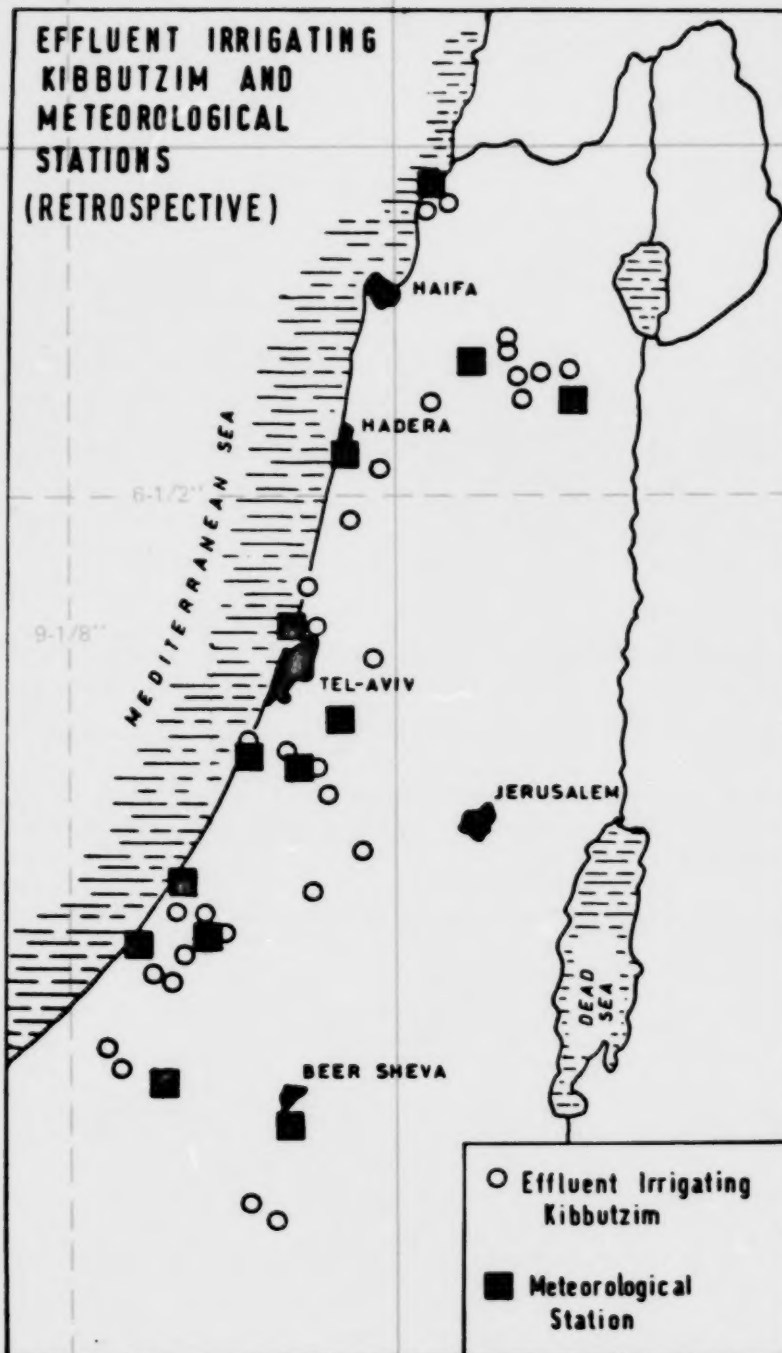


Figure 2. Geographical distribution of effluent irrigating kibbutzim and meteorological stations

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Check for Logical Errors

The data were punched onto diskettes and transferred onto a magnetic tape stored on the CDC Computer at the Hebrew University. Logical tests were carried out on these data in order to detect errors caused by incorrect entry of information or improper completion of the medical forms. All errors were corrected by the programmer. The following list covers the types of errors encountered which were checked by a special computer program designed to perform logical tests.

1. The code of the kibbutz is incorrect.
2. The number of the kibbutz does not correspond to its code.
3. The sex examined is not 0,1 or 2.
4. The month of birthdate does not fall between 1 and 12.
5. The first visit to the kibbutz clinic does not fall between the years 1920-1977. (This is based on the fact that the kibbutzim in the study did not exist before 1920, while our study period ended in 1977.)
6. The year of birth is later than the year of the first visit to the clinic.
7. The type of population does not fall between 1-7.
8. The disease code number does not fall between 1-24.
9. The day of the recorded visit to the clinic does not fall between 1-31.
10. The month of the recorded visit does not fall between 1-12.
11. The year of a recorded visit to the clinic does not fall between 1974-77. (Does not apply to switch category.)
12. The year of a recorded visit to the clinic in relation to each coded disease precedes the year of the first visit.
13. The code for laboratory tests does not fall between 1-5.
14. The population code number was 3 (child) while the patient was born before 1956.
15. Letters appear instead of numbers in the patient's data.

The results of the logical tests for categories I-III are summarized in Table 3. A total of 817 errors (2.78 percent) were found and corrected. Similar rates of errors for the switch category were detected and corrected.

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More than 50 percent of the errors resulted from mistakes in punching and the remainder from mistakes in filling out the medical forms.

Definition of Episode

The analysis of the 11 kibbutzim in the switch category (IV) was carried out as a pilot phase of the study and was based on the use of clinic visits rather than episodes. It was decided that for analysis of the data on the remaining 68 kibbutzim (I-III), episodes would be used as the response variable rather than clinic visits.

The question of defining episodes has been considered by numerous researchers (Logan and Cushion, 1958; Office of Population Census and Surveys, 1974; Yekutieli, 1981) and no general agreement exists.

For the purpose of this study, the 24 diseases were divided into two major groups. The first group included the following six diseases (two enteric and four control): Typhoid Fever, Infectious Hepatitis, Measles, Chickenpox-Varicella, Rubella, and Mumps.

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TABLE 3. TOTAL NUMBER OF LOGICAL ERRORS DETECTED FOR CATEGORIES I-III*

Type of Error	Number of Errors	Percent of Errors
1	0	0
2	0	0
3	13	0.04
4	20	0.07
5	145	0.49
6	158	0.54
7	2	0
8	90	0.31
9	79	0.27
10	153	0.52
11	0	0
12	0	0
13	48	0.16
14	105	0.36
15	4	0.01
	817	2.78

*Total Number of Cases: 29,632

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For this group episodes were defined as follows: Only one episode/ person for any of the diseases listed above during the four-year study period would be recorded, regardless of the actual number of recorded clinic visits for the specific disease. This is based on the assumption that these diseases generally provide lifetime immunity.

Eighteen diseases were included in the second group, ten of which were considered "enteric", six "control" and two "other" (influenza and food poisoning). Here the first clinic visit recorded for any of the diseases listed below was considered an episode. Further episodes of this same disease were then determined if a clinic visit occurred after a 30-day interval from the last previously recorded visit. If, however, a single episode continued over a period of 365 days, manifested by a series of visits, each one of which had an interval of less than 30 days, then a second episode is counted after 365 days.

Paratyphoid

Salmonella Infections

Bacillary Dysentery 6-1/2"

Gastro-Enteritis

Aseptic Meningitis

Upper Respiratory Infections

Influenza

Urinary Tract Infections

Food Poisoning

Fever of Unknown Origin

Coxsackie Virus Infection

Throat Infections

Accidents

Pneumonia

Bronchitis

Parasitic Infections

Amebiasis

Leptospirosis

ANALYSIS OF THE 68 KIBBUTZIM BY THE LOGISTIC AND THE LOG LINEAR MODELS

The Different Approaches Considered and Their Rationale.

In order to control for as many as possible of the complex risk and confounding factors which have a direct influence on the questions under study, a regression type of model, which relates the disease rates to multiple risk and confounding factors, should be used.

Two types of models capable of fulfilling these requirements have been used. The log linear and the logistic (Haberman, 1978 and Imrey, Koch and Stokes, 1981, 1982). However, as a first stage in the analysis the crude rates for the enteric and control diseases will be shown in graphic form as a preliminary presentation.

One of the main problems in this data set was the possible variation in the quality of reporting of clinic visits among the kibbutzim. If it was assumed that the individual kibbutz reporting rates were similar for total enteric diseases and total control diseases, then the ratio of total enteric to total control disease would overcome, to some extent, deviations in reporting. This assumption motivated the use of the logistic model based on

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total enteric to total control disease ratio. The model does not assume, however, a similar reporting ratio for enteric and control diseases and includes a reporting factor as a covariate. A formal statistical justification of this appears below.

In the logistic and log linear models, total control diseases were used as presented in Table 1, with the following exception: "throat infections" included only laboratory-confirmed streptococcal throat infections. The justification for this change was that the laboratory-confirmed streptococcal throat infection is known not to be a wastewater borne disease, and thus not associated with wastewater utilization. This has been done as a further refinement to eliminate any possible introduction of an additional confounding factor, even though throat infections are generally not considered as potentially water borne. It can be seen from Table 13 that laboratory-confirmed cases of this disease constitutes only 23 percent of total episodes of throat infection.

Although it would have been preferred to apply both models to specific enteric diseases such as Salmonellosis and Shigellosis in addition to the total enteric disease group, it was determined that this was not feasible due to the relatively small number of cases of specific diseases in each kibbutz. Thus, this analysis had to be limited to total enteric disease and total control disease.

Another problem of the data set was that the population data were based not on an exact census, but on a surrogate figure derived from the number of patient files in each kibbutz clinic. It was difficult to determine the degree of bias caused by the use of these estimates of population. The use of enteric to control disease ratios eliminates the population size from the rates denominators. To control for the effect of the population size on the ratio of enteric to control diseases the variable was entered into the logistic model as a covariate.

The log linear model used the estimated population of each kibbutz as the basis for the actual rates of enteric and control disease episodes. To control for the quality of reporting, the total control disease rate is entered as one of the explanatory variables for enteric diseases. The formal description of the log linear model follows.

It was recognized that there were many limitations in a complex data set such as this, derived from a retrospective study. Further, there were limitations to each one of the models used. However, it was assumed that with the use of both models, it would be possible to control for many of the confounding factors, and if the results of both analyses pointed in the same direction, this could be considered strong supportive evidence as to the validity of the findings.

Problems Arising From Seasonal Disease Patterns

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Experience in Israel, and elsewhere under similar climatic conditions has shown that the enteric diseases used in this study show a peak in the hot summer months, while the control diseases peak during the colder winter

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months (see Figure 21 for monthly disease distribution patterns in the kibbutzim in this study).

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In Israel, the hot summer months also coincide with the dry season with no rainfall, during which irrigation is most commonly practiced. Figure 4 and Table 7 show the seasonal distribution of the irrigation period among the categories of kibbutzim I-III. However, many local, regional and agroeconomic factors influence the number of months of actual irrigation practiced in each kibbutz, with some irrigating only during a short period of three summer months, while others irrigate for ten to twelve months.

Comparison of disease rates based on irrigation periods may be distorted by differences in the length of the irrigation period and its position in the annual cycle. For example, a kibbutz irrigating during the months of June-August, at the peak of the natural enteric disease cycle, will have a higher mean monthly enteric disease rate during the "irrigation period" than a kibbutz exposed to the same risks, but irrigating from February to November. The calculated mean monthly enteric disease rate for the "irrigation period" of the latter will be lower, since both normally high and low enteric disease periods were included in the calculation.

To control for these confounding factors two variables were introduced into the models. The first was an interval variable which represented the actual number of months of irrigation, i.e., the length of the irrigation period. This was based on the observation which indicated that the length of the irrigation period under the conditions of this study was negatively correlated with enteric disease rate and positively correlated with the control disease rate during the irrigation period. The second was a nominal variable which represented the position in the annual cycle when irrigation was initiated. Group 1 included those kibbutzim which irrigate all winter (12 months a year) or start irrigating in March. Group 2 included those starting irrigation in the Spring (April or May), while Group 3 started irrigation late in the spring or early summer. Detailed definitions of all the variables which enter into the model are presented later.

The above variables entered into the model when disease rates during irrigation periods, as actually practiced in each kibbutz, were compared.

Another approach, used to control for the confounding effect associated with the natural seasonal disease cycle, was to examine the association between wastewater utilization and disease rate during the warm summer season (May-August) and the cold winter season (November-February), approximately congruent with the high enteric disease period and the low enteric disease period. This analysis by fixed four-month time periods was considered a way of overcoming some of the confounding effects of the analysis by "irrigation period".

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Two different procedures were used. In one case, we compared those kibbutzim which irrigate only during the above mentioned summer months and do not irrigate during the winter period. This limited the number of kibbutzim to 29: 14 from category I, 8 from II and 7 from III. A second

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procedure encompassed all 68 kibbutzim in the study, regardless of actual irrigation periods, but compared disease rates only for the above months.

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Still another way of examining the same data set was to compare the annual disease rates for enteric and control disease of all kibbutzim in the three categories, regardless of irrigation period and length of exposure to wastewater utilization. This approach compares the overall public health impact on the community of wastewater utilization.

A Formal Presentation of the Models and Their Assumptions Notation:

The two models derived from different distributional assumptions of the individual's clinic visits for enteric and control diseases. The time of occurrence of individual clinic visits for enteric and control diseases are shown to follow a seasonal pattern and hence a Non Stationary Point Process (Cox and Snell, 1966).

As stated previously, the two models were applied to different data sets. The most complex models were applied to irrigation - non-irrigation data. The models applied to the summer-winter data set were of similar form but did not include the covariates introduced to control for different irrigation periods. The models applied to the annual, summer and winter data sets also did not include the covariates introduced to control for the effect of the two periods. A detailed description of the model applied to the irrigation - non-irrigation data is given below.

Denote by: E_{sijklm} , C_{sijklm} , the total number of enteric and control diseases for an individual s during period i (1-irrigation; 2-non-irrigation) who belongs to age group j (1-age group 0-4; 2-age group 5-17; 3-age group 18+) in calendar year k (1-1974; 2-1975; 3-1976; 4-1977) in kibbutz l , which utilizes wastewater for use m (1-effluent irrigation; 2-non-effluent irrigation; 3-fish pond enrichment).

T_{i1} - the length in months of period i in kibbutz 1 (the irrigation period has the same length for each calendar year).

N_{j1} - the size of population in age group j in calendar year k in kibbutz 1.

The Logistic Model

The logistic model assumes that:

(1) $E_{sijklm} \sim \text{Poisson} (T_{i1} \cdot \delta_{sijklm} \cdot \theta_{ijklm}^E)$

(2) $C_{sijklm} \sim \text{Poisson} (T_{i1} \cdot \delta_{sijklm} \cdot \theta_{ijklm}^C)$

(3) E_{sijklm} and C_{sijklm} are independent.

(4) The total number of enteric and control diseases for different individuals are independent.

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- (5) The total number of enteric and control diseases in a kibbutz during different years and periods are independent.

This model assumes that the number of enteric and control diseases for an individual in each period follows Poisson distribution with means which differ from individual to individual. The two means were further assumed to be a product of two parameters: the individual parameter θ_{ijklm} which depends on the period, year, kibbutz and age group, but not on the type of disease, and a parameter which depends on the type of disease, but not on the individual. The Poisson distribution is often used (Kilpatrick, 1977; Ashford and Hunt, 1974) to characterize the distribution of individual clinical visits.

The independence assumptions (4) do not hold exactly since some of the diseases were communicable and (4) and (5) are used only as a crude approximation to reality.

The assumptions made imply that:

$$E_{ijklm} | (C_{ijklm} + E_{ijklm}) \sim B(P_{ijklm}, E_{ijklm} + C_{ijklm})$$

Where $B(P,n)$ is the Binomial distribution with parameters (P,n) and

$$\text{Where } P_{ijklm} = \frac{\theta_{ijklm}^E}{\theta_{ijklm}^E + \theta_{ijklm}^C}$$

$$\text{Let } E_{ijklm} = \sum_s E_{sijklm}, C_{ijklm} = \sum_s C_{sijklm}$$

The independence between individuals further implies that:

$$E_{ijklm} | (E_{ijklm} + C_{ijklm}) \sim B(P_{ijklm}, E_{ijklm} + C_{ijklm})$$

E_{ijklm} are independent for different values of (i,j,k,l,m) .

The logistic model provides a relatively simple model for P_{ijklm} - the probability that a diseased (enteric or control) individual has an enteric disease.

The model is best expressed in terms of $P_{ijklm}/(1-P_{ijklm})$ - the odds of having an enteric disease.

Denote by X_{ijklm} a vector of risk and confounding factors which is assumed to be related to the odds of enteric disease.

The logistic model assumes that log of enteric diseases odds is a linear function of these risk and confounding factors, i.e.:

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$$\log \frac{P_{ijklm}}{1 - P_{ijklm}} = \alpha + \sum_{ijklm} \beta_{ijklm}$$

where β is the vector of unknown coefficients.

The Log Linear Model

The log linear model assumes that:

$$(1) \quad E(E_{sijklm}) = T_{i1} \cdot \mu_{ijklm}$$

$$\text{Var}(E_{sijklm}) = \sigma_j^2 T_{i1} \mu_{ijklm} \text{ for some } \sigma_j^2 > 0$$

(2) The number of enteric diseases for different individuals are independent.

(3) The number of enteric diseases during different years and periods in the same kibbutz and among kibbutzim are independent.

The parameter μ_{ijklm} is assumed to characterize the distribution of the number of clinical visits for all the individuals in age group j in kibbutz l (which utilizes wastewater for method m) during period i of calendar year k . This parameter represents the constant rate of occurrence if the process in each period is stationary, and an "average" rate of occurrence if the process is non-stationary. The ratio of the variance to the mean is further assumed to be constant for all individuals in an age group during all periods in all kibbutzim.

This model reduces to the assumption that the number of enteric diseases follows a Poisson distribution if $\sigma_j^2 = 1$. According to Baker and Nelder (1978), the model serves as a reasonable approximation to the negative binomial model (Johnson and Kotz, 1969) if $\sigma_j^2 > 1$. This model's assumptions are therefore much weaker than the ones employed by the standard log linear model for multi-Poisson vectors.

The total enteric diseases for all individuals in age group j in kibbutz l during period i in year k is thus distributed as:

$$E(E_{ijklm}) = N_{jkl} \cdot T_{i1} \cdot \mu_{ijklm}$$

$$\text{Var}(E_{ijklm}) = \sigma_j^2 N_{jkl} \cdot T_{i1} \cdot \mu_{ijklm}$$

The corresponding rate of occurrence of enteric diseases per subject per month is defined by:

$$R_{ijklm} = E_{ijklm} / (N_{jkl} T_{i1})$$

Let Z_{ijklm} denote a vector of risk and confounding factors assumed to be related to the rate of occurrence of enteric diseases per subject per month (a detailed definition of these factors is given below starting with the Risk and Confounding Factors Considered).

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The log linear model assumes that the log of enteric disease rate is a linear function of the risk and confounding factors, i.e.:

$$\log (\mu_{ijklm}) = \eta + \sum_{i,j,k,l,m} \gamma_{ijklm} \cdot x_{ijklm}$$

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where γ is a vector of unknown coefficients. Models of this type have been considered by Haberman (1978), Holford (1980) and many others.

The Risk and Confounding Factors Considered

Age was assumed to modify the effects of the risk and confounding factors. To avoid the inclusion of all its interactions with the other factors in the model we chose to perform a separate analysis in each of three age groups: 0-4, 5-17, 18+. In each calendar year individuals are grouped according to their age. Individuals may thus be included in more than one age group over the course of the study.

All the analyses consider the risk of enteric diseases associated with the three kibbutz categories (KC) while controlling for some of the following risk and confounding factors:

(1) Period--

The risk of enteric diseases was examined during the irrigation and non-irrigation periods. The factor enters the model as:

$$IRR = \begin{cases} -1 & \text{irrigation period} \\ 1 & \text{non-irrigation period} \end{cases}$$

(2) Months of Irrigation Period--

The distribution of the irrigation period in each of the three categories are presented later in Tables 6 and 7.

Table 7 shows that the months of irrigation are either: A. Spring-Autumn, or B. Spring-Summer, or C. Spring-Winter. The following two dummy variables were chosen to represent these differences in the position of the irrigation period in the cycle year:

$$MIP1 = \begin{cases} 1 & \text{irrigation period starts in April or after} \\ & \text{and ends in September or before.} \\ 0 & \text{irrigation period starts in April or May} \\ & \text{and ends in October or November.} \\ -1 & \text{irrigation period starts in March or before} \\ & \text{and ends in September or after.} \end{cases}$$

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MIP2 =

- { 1 irrigation period starts in April or May and ends in October or November.
- { 0 irrigation period starts in April or after and ends in September or before.
- { -1 irrigation period starts in March or before and ends in September or after.

(3) Length of Irrigation Period--

The length of irrigation period enters into the model as:

$$LIP = \begin{cases} \text{length of irrigation period } (T_1) & \text{if } IRR = -1 \\ 0 & \text{other.} \end{cases}$$

(4) Length of Non-Irrigation Period--

This factor enters into the model as:

$$LNIP = \begin{cases} \text{length of non-irrigation period } (T_2) & \text{if } IRR = 1 \\ 0 & \text{other.} \end{cases}$$

(5) Geographical Region of the Kibbutz--

Geographic location of the kibbutz may have an influence on disease rates. For example, in the northern region water supplies are more plentiful and rainfall is greater. This leads to shorter irrigation periods. Another possible confounding influence is the fact that the northern kibbutzim utilize surface water sources exposed to pollution more frequently than those in the central or southern regions, which mainly use ground water. There may also be climatic factors or specific regional disease patterns of undetermined nature.

The differences between the northern, central and southern regions were measured by the following two dummy variables:

$$REGION\ 1 = \begin{cases} -1 & \text{North} \\ 0 & \text{Central} \\ 1 & \text{South} \end{cases}$$

$$REGION\ 2 = \begin{cases} -1 & \text{North} \\ 1 & \text{Central} \\ 0 & \text{South} \end{cases}$$

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(6) Type of Crop Grown in the Field Irrigated With Sewage--

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The dominant type of crop irrigated may have an influence on disease patterns since, for example, cotton is usually irrigated only for a short period during the peak summer months and plots of fodder crops were usually located closer to the residential areas than other crops and were irrigated for longer than average periods. Irrigation sprinklers for corn are placed higher above the ground and thus may lead to greater dispersion of aerosols of sewage origin. The variables enter the model as:

CROP = $\begin{pmatrix} -1 & \text{wheat, barley, sorghum, plantations} \\ 1 & \text{cotton + other} \\ 0 & \text{non-sewage irrigation} \end{pmatrix}$

(7) Calendar Year--

Disease rates may vary from year to year. To control for this confounding factor, the following variables were introduced:

YEAR 1 = $\begin{pmatrix} -1 & \text{year 1974} \\ 1 & \text{year 1977} \\ 0 & \text{other} \end{pmatrix}$

YEAR 2 = $\begin{pmatrix} -1 & \text{year 1974} \\ 1 & \text{year 1976} \\ 0 & \text{other} \end{pmatrix}$

YEAR 3 = $\begin{pmatrix} -1 & \text{year 1974} \\ 1 & \text{year 1975} \\ 0 & \text{other} \end{pmatrix}$

(8) Source of Sewage Utilized for Irrigation--

It was assumed that there will be a substantive difference in the types of pathogens in sewage derived from the kibbutz itself as compared to sewage drawn from neighboring urban communities. While the kibbutz's own sewage was expected to contain mainly pathogens of diseases already endemic in the community, it might be anticipated that sewage from another source will carry pathogens not endemic in the kibbutz itself, thus creating a greater risk of infection.

The factor enters the model as:

SI = $\begin{pmatrix} -1 & \text{non local with others} \\ 1 & \text{local with others} \\ 0 & \text{non sewage irrigation} \end{pmatrix}$

(9) Source of Non-Sewage Irrigation Water--

It was expected that in some cases, non sewage irrigation water could contain levels of microbial contamination greater than others. For example, irrigation with polluted river water would be a greater health risk than irrigation with well water.

The variable enters the model as:

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NSI = $\begin{cases} -1 & \text{Mekorot well, national pipeline,} \\ & \text{well of the kibbutz} \\ 1 & \text{lake, stream and drainage water} \end{cases}$

(10) Source of Drinking Water--

Detailed data on microbial quality of drinking water in each kibbutz was not available; however, it was expected that those communities deriving drinking water from polluted surface sources were exposed to potentially greater risks than those consuming water from local wells while the safest water was derived from the well operated and monitored National Pipeline which is disinfected.

The following two variables were chosen to represent this factor:

SDW1 = $\begin{cases} -1 & \text{National Pipeline} \\ 1 & \text{Lake water and Jordan River} \\ 0 & \text{Local sources} \end{cases}$

SDW2 = $\begin{cases} -1 & \text{National Pipeline} \\ 1 & \text{Local sources} \\ 0 & \text{Lake water and Jordan River} \end{cases}$

(11) Disinfection--

A disinfection installation may influence disease rates in the kibbutz. To control for this risk factor, the following variable was defined:

DIS = $\begin{cases} -1 & \text{the drinking water was disinfected} \\ 1 & \text{the drinking water was not disinfected} \end{cases}$

(12) Political Movement of the Kibbutz--

The kibbutzim in Israel belong to three major political movements: Hakibbutz Haartzi, Hakibbutz Hameuchad and Ha'ihud and Hakibbutz Hadati. The three were known to differ in some ways in their lifestyle. The assumption was that this difference may affect the disease rates in the kibbutz. The following two dummy variables were used to enter this factor into the model:

PMOV1 = $\begin{cases} -1 & \text{Hakibbutz Haartzi} \\ 0 & \text{Hakibbutz Hadati} \\ 1 & \text{Hakibbutz Hameuchad} \\ & + \text{others} \end{cases}$

PMOV2 = $\begin{cases} -1 & \text{Hakibbutz Haartzi} \\ 1 & \text{Hakibbutz Hadati} \\ 0 & \text{Hakibbutz Hameuchad} \\ & + \text{others} \end{cases}$

(13) Volume of Sewage Used for Irrigation--

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The preliminary analysis indicates that the risk of enteric disease associated with the volume of sewage used for irrigation can be detected if the variable enters the model as:

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$$VOL = \begin{cases} \text{(volume of sewage used for irrigation in category I)} \\ 0 & \text{if the kibbutz belongs to categories II or III} \end{cases}$$

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(14) The Rate of Total Clinical Visits per Person--

As stated previously, the quality of reporting varies considerably among the kibbutzim. This study assumes that the rate of total clinical visits per person (TVPP) in that kibbutz is a good proxy to the quality of reporting in the kibbutz. This assumption is supported by our prospective study.

(15) The Size of Population in the Kibbutz--

The size of population in the kibbutz may affect differently the transmission of enteric and control diseases. The logistic model for a specific age group controls for this confounding factor by entering into the model the variable POP, which takes the values of the size of the age group under study in the kibbutzim.

(16) The Rate of Control Diseases--

The control disease group includes upper respiratory infections and other clinical conditions which may be etiologically associated with enteric viruses of a sewage origin and thus may be affected by wastewater utilization practice. The rate of control diseases is further assumed to be proxy for the unobservable quality of reporting in the kibbutz.

The log linear model measured, therefore, the excess of enteric diseases from a level determined by the rate of control diseases.

The risk and confounding factors included in the logistic and log linear models for each set of disease rates are given in Table 4. Among them the following interactions are:

(A) Kibbutz category x Period (KC x IRR)--The inclusion of the above interaction in the model enables the comparison of the risk associated with wastewater utilization during irrigation and non-irrigation periods.

(B) Kibbutz category and period length (KC x LIP, KC x LNIP)--The inclusion of these interactions in the model reflects the assumption that an increase in the length of irrigation period is associated with different risks of enteric diseases in the three kibbutz categories.

(C) Year x region x crop--The risk of enteric diseases associated with the crop grown in the irrigated field during each calendar year was assumed to depend on the geographical region.

(D) Source of drinking water x Disinfection (SDW x DIS)--The risk associated with the source of drinking water in the kibbutz is assumed to depend on the existence of disinfection installation.

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TABLE 4. THE HIGHER ORDER INTERACTION OF EXPLANATORY VARIABLES INCLUDED IN LOGISTIC AND LOG LINEAR MODELS FOR EACH OF THE DISEASE RATES

Set of Disease Rates	Model	Higher order interaction of explanatory variables included in the model
Irrigation	Logistic	KC x IRR, MIP, KC x LIP, KC x LNIP, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, POP
	Log Linear	KC x IRR, MIP, KC x LIP, KC x LNIP, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, log $\frac{CONTROL}{POP \times LP}$
Summer	Logistic	KC x IRR, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, POP
	Log Linear	KC x IRR, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, log $\frac{CONTROL}{POP \times LP}$
Annual	Logistic	KC, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, POP
	Log Linear	KC, YEAR x REGION x CROP, SI, NSI, SDW x DIS, PMOV, VOL, TVPP, log $\frac{CONTROL}{POP \times LP}$

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The other higher order interactions were not included in the model because no a priori basis for their inclusion could be found.

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It should be noted that the models considered did not control for all the risk and confounding factors associated with each kibbutz. Such control could have been accomplished only if the higher order interaction between all the explanatory variables considered would have been included in the model. This saturated model has not been fitted to the data because of computational difficulties.

The Data Used in Each Study

Each of the three age groups in each kibbutz contributes 8 "observations" (2 for each calendar year) to the summer-winter study and 4 "observations" to the annual data set and to the separate analysis of the summer and winter periods.

A kibbutz which irrigated only part of the calendar year contributes 24 "observations" (8 for each age group) to the irrigation - non-irrigation study. A kibbutz which irrigated throughout the year contributes only 12 "observations" (4 for each age group) to the above study.

Estimation Methods for the Logistic Model

The non-significant risk and confounding factors are deleted from the model by the BMDP-LR backward stepwise procedure. The parameters of the selected model were estimated by the maximum likelihood method through the Newton-Raphson procedure. Tests for the significance of the coefficients were based on the asymptotic theory for maximum likelihood estimates. The estimated coefficients and their asymptotic variances and covariances are then used to construct the estimated odd ratios associated with wastewater utilization.

Estimation Methods for the Log Linear Model

The model is fitted to the data by the BMDP-1R multiple linear regression program. This program was preferred over the stepwise regression program because the latter disregards the polytomous nature of most of the categorical risk and confounding factors and treats each explanatory dummy variable as a "variable" by itself.

The parameters of the model were estimated by the weighted least squares method. The weights

$$W_{ijklm} = E_{ijklm}$$

estimate the inverse of the variances of $\log \frac{E_{ijklm}}{T_{i1} \cdot N_{jk1}}$. The use of Taylor

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approximation indicates that under the assumption $E[E_{ijklm}] = N_{jk1} \cdot T_{i1} \cdot \mu_{ijklm}$

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the variance of $\log \frac{E_{ijklm}}{T_{il} \cdot N_{jkl}}$ is approximately given by:

$$\text{Var } \log \frac{E_{ijklm}}{T_{il} \cdot N_{jkl}} \approx$$

$$\frac{1}{\mu_{ijklm}^2} \text{Var } \frac{E_{ijklm}}{T_{il} \cdot N_{jkl}} = \sigma_j^2 \frac{1}{\mu_{ijklm}^2} \cdot \frac{\mu_{ijklm}}{T_{il} \cdot N_{jkl}} = \frac{1}{\mu_{ijklm} \cdot T_{il} \cdot N_{jkl}}$$

This weighted least squares is known to be asymptotically efficient (BAN) (Grizzle, Stammer and Koch, 1969; Bhapkar, 1981) if the model fits the data. Tests of significance were based on the asymptotical normality of the estimates. The coefficients and their variances and covariances are then used to construct the estimate of the relative risks associated with wastewater irrigation. In all analyses the given significance level must be considered to be approximate only. To overcome the problem of zero counts for enteric and control clinical visits, they were replaced by 1/2. This type of adjustment is suggested in Bhapkar (1981).

THE SWITCH CATEGORY ANALYSIS BY THE LOGISTIC AND THE LOG LINEAR MODELS

The Importance of the Switch Category Study

The differences in the risk of enteric diseases between kibbutzim which utilize effluent water for irrigation and other kibbutzim which do not utilize effluent have been shown to depend on various characteristics, such as: the length of irrigation period, and its position in the yearly cycle, the quality of reporting in the kibbutz, the geographical region of the kibbutzim in the two categories and possibly many other unidentified Kibbutz specific factors. The difference between the risk of enteric diseases associated with the two methods of irrigation is thus confounded by those characteristics. These confounding factors have to be fully controlled for before any conclusions are to be reached.

An adjustment for such inter-kibbutz confounding factors is not necessary in the switch category analysis since each kibbutz in this category utilizes both effluent and non-effluent for irrigation for two consecutive years and serves as the control for itself. Although some intra-kibbutz confounding factors have been changed during the study period, one can view the switch category design as a complete block type design with effluent and non-effluent irrigation as treatments and kibbutz as a block.

To efficiently estimate the odds ratios and relative risks of enteric diseases for effluent vs. non-effluent irrigation, the logistic and log linear models have to include the kibbutz effect among their explanatory variables.

Disease rates for two different periods are used to assess the risk of enteric diseases associated with effluent irrigation. The first was the

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"period of exposure to risk", i.e., the irrigation period, and the second was the annual enteric disease rate.

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Comparison of the annual disease rates of enteric diseases for effluent and non-effluent years is important from an overall public health point of view.

In this analysis it was decided that estimation of the enteric disease risk for a fixed arbitrary summer and winter period as done in the analysis of the 68 kibbutzim was not appropriate. For the 68 kibbutzim it was difficult to compare disease rates in two different categories (I vs. II) when each individual kibbutz had a different period of exposure, i.e., irrigation period. Although these differences had been controlled for to some extent by the introduction of "length of irrigation period" and "position of irrigation period" as covariates into the log linear and logistic models, the comparison of the enteric disease rates in the same kibbutzim for fixed time periods (summer and winter) was felt to be essential. In the switch category, the rate of enteric disease during the irrigation period with effluent and without effluent is always a comparison within the same kibbutz for the exact same time period. Thus, it was not felt to be proper to limit the analysis in any way to arbitrary fixed seasonal periods. The strength of the switch category design lies in not requiring such manipulations.

A Formal Description of the Models

Five of the kibbutzim in the switch category switched from non-effluent to effluent irrigation while six switched from effluent to non-effluent.

Let E_{jlgkm} and C_{jlgkm} denote the number of enteric and control diseases during irrigation period (the whole year) in age group j (1-age group 0-4; 2-age group 5-17; 3-age group 18+) in kibbutz l ($l=1, 2, \dots, 11$) which belongs to switch category g (1-from non-effluent to effluent; 2-from effluent to non-effluent) during year k (1-first year; 2-second year) of irrigation with method m (1-effluent; 2-non-effluent) and let:

T_l denote the length of irrigation period in kibbutz l ;

N_{jl} denote the size of population in age group j of kibbutz l ;

X_{jlgkm} denote the vector of risk and confounding factors which we assumed to be related to E_{jlgkm}/C_{jlgkm} .

The logistic model's main assumption is that:

$$\text{Log } \frac{P_{jlgkm}}{1-P_{jlgkm}} = \alpha + X'_{jlgkm} \beta$$

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where P_{jlgkm} is the mean of the binomially distributed proportion $E_{jlgkm}/(E_{jlgkm} + C_{jlgkm})$ and $\underline{g}$ is the vector of unknown coefficients.

The log linear model's main assumption is that:

$$\log(\mu_{jlgkm}) = n + \underline{X}'_{jlgkm} \underline{\gamma} + \log\left(\frac{C_{jlgkm}}{T_{1j1} N_{j1}}\right) \gamma_c$$

where:

$$E[E_{jlgkm}] = N_{j1} T_{1j1} \mu_{jlgkm}$$

$$\text{Var}[E_{jlgkm}] = \sigma^2 N_{j1} T_{1j1} \mu_{jlgkm}$$

and $\underline{\gamma}$, γ_c are unknown coefficients.

The log of control diseases rate enters into the model to control for possible differences in the quality of reporting in the same kibbutz over the years.

The two models' other assumptions were described and discussed in detail previously.

Both the logistic and log linear models consider the following risk and confounding factors:

(1) Use of Effluent for Irrigation--

$$\text{EFF} = \begin{pmatrix} -1 & \text{non-effluent} \\ 1 & \text{effluent} \end{pmatrix}$$

(2) The Form of Switch--

$$\text{GKIB} = \begin{pmatrix} -1 & \text{from non-effluent to effluent} \\ 1 & \text{from effluent to non-effluent} \end{pmatrix}$$

(3) Age Groups--

$$\text{AGE 1} = \begin{pmatrix} -1 & \text{Age 0-4} \\ 0 & \text{Age 5-18} \\ 1 & \text{Age 19+} \end{pmatrix}, \quad \text{AGE 2} = \begin{pmatrix} -1 & \text{Age 0-4} \\ 1 & \text{Age 5-18} \\ 0 & \text{Age 19+} \end{pmatrix}$$

4) Year of Operation for Each Irrigation System--

$$\text{YEAR} = \begin{pmatrix} -1 & \text{the method of irrigation is observed in its first year} \\ 1 & \text{the method of irrigation is observed in its second year} \end{pmatrix}$$

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The kibbutz effect is nested within the effect of the form of the switch. The dummy variables for the kibbutzim which switched from non-effluent to effluent were chosen to measure the difference between their effects and the effect of a reference kibbutz (denoted by kibbutz 1) in this category. The five dummy variables for the kibbutzim in that category were defined as:

$$K1(I) = \begin{cases} -1 & \text{for kibbutz 1} \\ 1 & \text{for kibbutz I} \\ 0 & \text{else} \end{cases}$$

where $I = 2, 3, \dots, 6$.

The dummy variables for the kibbutzim which switched from effluent to non-effluent were similarly defined as:

$$K2(J) = \begin{cases} -1 & \text{for kibbutz 1} \\ 1 & \text{for kibbutz J} \\ 0 & \text{else} \end{cases}$$

where $J = 2, 3, \dots, 5$.

Denote by $\beta_1(I)$, $\beta_2(J)$, $\gamma_1(I)$, $\gamma_2(J)$, the logistic and log linear coefficients for kibbutz I in the first switch category and J in the second switch category. Note that the definition of the kibbutz effects imply that:

$$\sum_{I=1}^5 \beta_1(I) K1(I) = \sum_{I=1}^5 \gamma_1(I) k1(I) = 0$$

$$\sum_{J=1}^4 \beta_2(J) K2(J) = \sum_{J=1}^4 \gamma_2(J) K2(J) = 0$$

a constraint which is common to all nested models.

This study has a special interest in the risk associated with EFF and GKIB and their interaction with AGE and YEAR, i.e.: EFF x GKIB x AGE, EFF x GKIB x YEAR, GKIB x AGE x YEAR. Inclusion of these interactions in the model enables the comparison of the risk associated with effluent and non-effluent irrigation in each age group and year in the two switch categories. Possible confounding factors are the KIBBUTZ effect, AGE, YEAR and the interactions K1 x EFF x AGE, K2 x EFF x AGE. These interactions enter into the models to control for possible differences in the odds ratios for effluent vs. non-effluent irrigation between populations of different kibbutzim. The methods used to estimate the parameters of the two models were described in detail previously.

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SECTION 5

RESULTS AND DISCUSSION

GENERAL

Kibbutz Size

The mean size of kibbutzim in category I was 451, in II was 396, in III was 501 and in category IV was 276. While the mean size for all kibbutzim was 414, the size range was 200 - 1012 in categories I-III and between 146-378 in category IV.

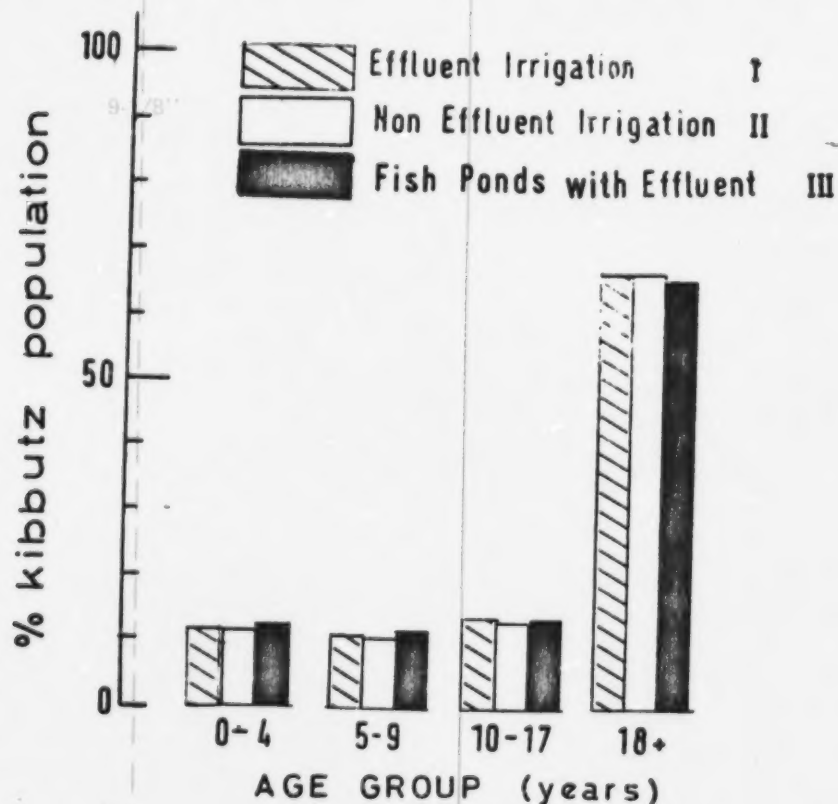


Figure 3. Age distribution by category

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The difference in mean size of kibbutzim in the various categories was not great. However, in order to control for any influence in disease transmission related to the kibbutz size, this parameter was introduced as a variable in the logistic and log linear models.

In any event, the size of the kibbutz was not of influence in the switch category, since that category dealt with the same kibbutz "before and after" a change in exposure to wastewater effluent.

Age Distribution

Figure 3 (previous page) and Table 5 present the age distribution by kibbutz category (I-III) of the 68 kibbutzim according to the four major age group breakdowns used throughout the study. The age distribution is almost identical in each of the three categories of kibbutzim, with about 10 percent of the population in each of the 0-4 and 5-9 age groups, 13 percent in the 10-17 age group and the remaining 66 percent in the 18+ age group. By inspection, no differences in the age distribution by sex were observed. This indicates that no differences in morbidity rates of the three categories due to different age or sex distributions should be expected in the 68 kibbutzim.

9-1 TABLE 5. AGE DISTRIBUTION BY KIBBUTZ CATEGORY

Age (years)	Effluent Irrigation (I)	Non-Effluent Irrigation (II)	Fish Ponds with Effluent (III)	Total
0-4	1276 (10.6)*	1218 (11.0)	586 (11.7)	3080 (10.4)
5-9	1446 (10.7)	1146 (10.3)	542 (10.8)	3134 (10.6)
10-17	1851 (13.7)	1367 (12.3)	632 (12.6)	3850 (13.0)
18+	8958 (66.2)	7365 (66.4)	3245 (64.9)	19568 (66.0)
Total	13531 (100.0)	11096 (100.0)	5005 (100.0)	29632 (100.0)

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* () Percent Total in Category

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Irrigation Period

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Figure 4 presents the distribution of the months of irrigation for the 68 kibbutzim of categories I-III, both combined and separately; the number of kibbutzim irrigating during particular months appear in each column in Figure 4.

Between 88 percent to 100 percent of the kibbutzim irrigate during the months of May-August, which we have defined as the summer irrigation period. Sixteen kibbutzim--or 24 percent--irrigated for the full 12 months of each year. Of those remaining kibbutzim which do not irrigate for 12 months a year, none irrigated in December, January or February, while 14--or 21 percent--irrigated in November. For the purposes of this study we have defined the months of November through February as the winter non-irrigation period. Normal span of the irrigation period was considered to extend from April to October during which 70 percent to 100 percent of the kibbutzim irrigated.

The mean number of months of irrigation for all categories is 7.6 months/year, while category I had a mean of 8.1 months/year, and II and III had means of 7.2 months/year (see Table 6).

TABLE 6. AVERAGE NUMBER OF IRRIGATION MONTHS BY CATEGORY

PERIOD	CATEGORY I	CATEGORY II	CATEGORY III	ALL CATEGORIES
IRRIGATION	8.07	7.18	7.20	7.57
NON- IRRIGATION	3.93	4.82	4.80	4.43

The distribution of the 16 kibbutzim that irrigate all year round, among the categories, is as follows: I and II, 7 each or about 24 percent; in category III, 2 kibbutzim or 20 percent.

Fifty-five percent of the kibbutzim in the southern region irrigate all year long, in comparison to 6 percent in the central area and 3 percent in the north (see Figure 5; the number of kibbutzim in each category appears in the column). The southern area, defined as the area from Jerusalem southward, includes 22 kibbutzim with an average of 9.3 months of irrigation per year.

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There are 16 kibbutzim in the central area, located between Jerusalem and Hadera, with an average of 7.0 months irrigation per year.

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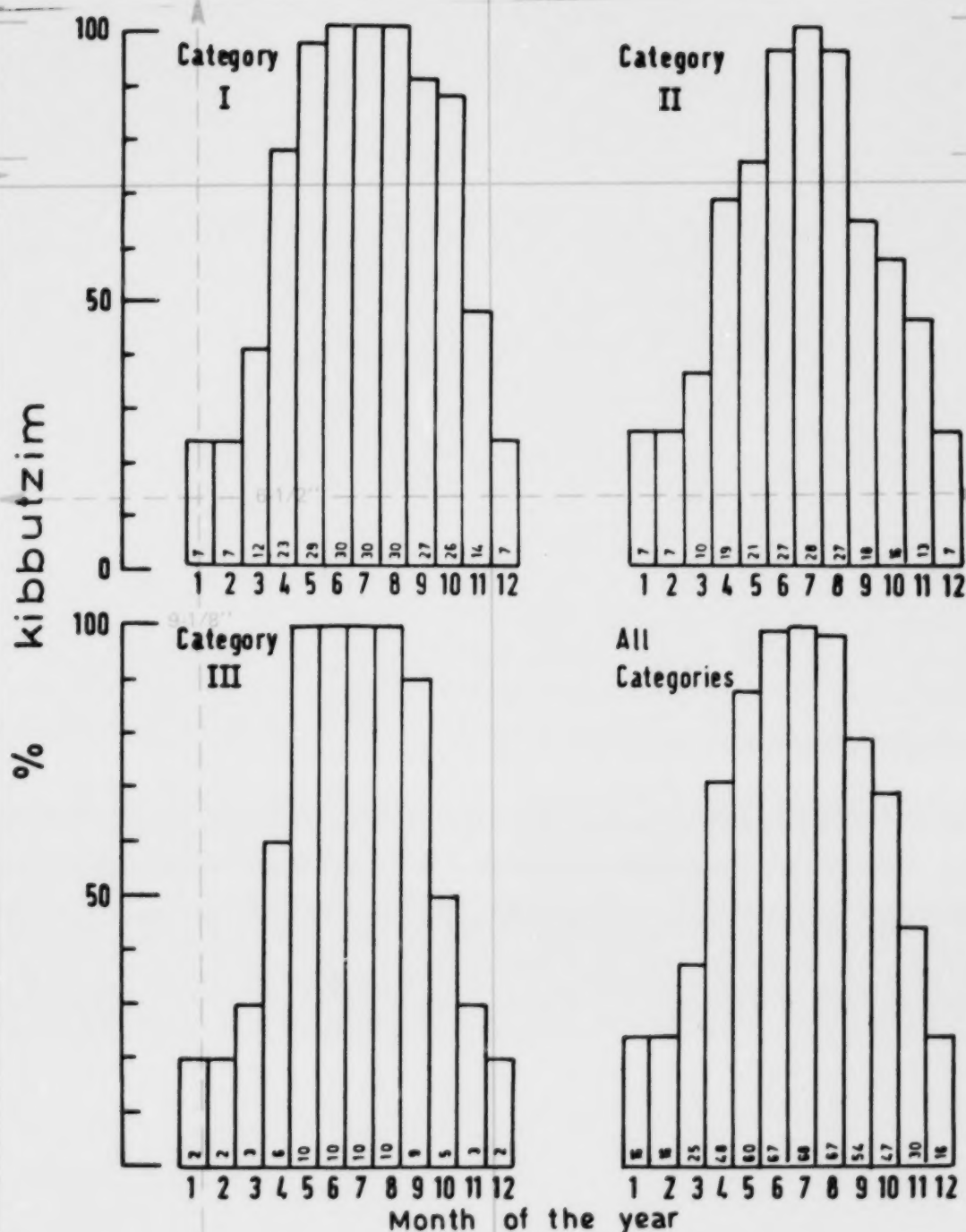


Figure 4. Distribution of irrigation period by month of the year in 68 kibbutzim by category (I-III). (Figures in columns are numbers of kibbutzim irrigating in a given month.)

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The northern area, covering Hadera and all points north, includes 30 kibbutzim with an average of 6.5 months of irrigation per year.

The ten kibbutzim of category III are all in the north while one-third of categories I and II are located in the North.

The average for all categories (7.6) is close to the monthly average for the northern and central areas, but 20 percent lower than the average for the southern area.

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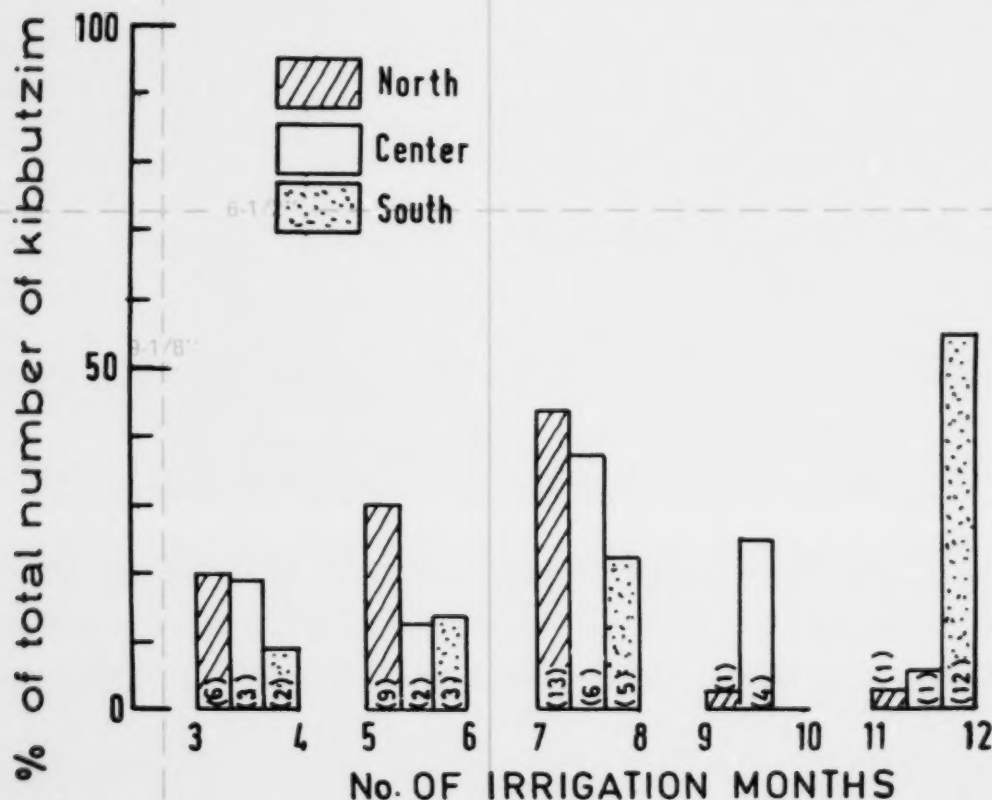


Figure 5. Distribution of irrigation period by months and by three geographical regions. (Figures in columns are numbers of kibbutzim irrigating in a given month.)

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The start of the irrigation period varies between the kibbutzim (see Table 7). While 16 irrigate all year long, 9 begin in March, 23 in April and 12 in May, with the remaining 8 starting in June. While in categories I

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and III, 96-100 percent of the kibbutzim began irrigation during March, April or May, only 68 percent of category II kibbutzim started irrigating during the above three months.

TABLE 7. THE DISTRIBUTION OF IRRIGATION PERIODS IN
THE THREE KIBBUTZ CATEGORIES

Irrigation Months		Effluent Irrig.	Non Effluent Irrig.	Effluent Enrichment of Fish Ponds
Starts	Ends			
1	12	7	7	2
3	9,10,11	5	3	1
4,5	10,11	14	6	3
4 or after	9 or before	4	12	4
		30	28	10
MEAN	9-1/8"	8.03	7.21	7.2

For effluent irrigating kibbutzim in category I, the irrigation period, as used in this study refers to those months in which effluent was used for irrigation. By inspection, the months of effluent irrigation in category I kibbutzim were found to coincide, in general, with the months of irrigation with non-effluent sources of water in category II also.

The peak summer irrigation season coincides in general with the annual high season for most enteric diseases, and the normal winter non-irrigation period with the annual low season of enteric disease, regardless of external environmental risk factors. Thus the question of exposure to risk by wastewater irrigation for different lengths of time ranging from 12 months in some cases, to 3 months in others, must control for the effect of seasonal disease cycles.

Similarly, kibbutzim in the northern region where rainfall is more plentiful irrigate fewer months per year than those in the dryer southern region. For the above reason, as well as others, the effect of geographical location must also be controlled. The month in which wastewater irrigation was initiated could also have had an influence on the pattern of enteric disease.

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In the data analysis, length of irrigation period, starting date of irrigation, and geographical location have all been introduced as controlling factors.

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EFFLUENT VS. NON-EFFLUENT KIBBUTZ CATEGORIES (I-III) - CRUDE RATES

Comparison of Clinic Visits to Episodes

In Figure 6a, we compared the number of clinic visits in each of the major disease groups with the number of laboratory confirmed diagnoses and with the number of episodes (as defined in Section 4 - Research Design). The total number of visits for each disease group is represented as 100 percent, with the number of episodes as well as the number of laboratory confirmed diagnoses in that disease group, as a percentage of the total number of clinic visits. For the four major disease groups, as well as the total number of diseases, the number of episodes varied between 90 and 96 percent of the total visits. Only about 18 percent of the clinic visits were identified as being associated with a laboratory confirmed diagnosis for the total enteric disease group. The figure for laboratory confirmed diagnoses was 81 percent for the group "selected enteric diseases" which excludes clinical gastroenteritis. Fifteen of the total control diseases were associated with laboratory confirmed diagnoses and only 3 percent of the selected control group visits are confirmed. For all diseases, 15 percent of the clinic visits were associated with laboratory confirmed diagnoses.

In Figure 6b all clinic visits, all episodes and all laboratory confirmed diagnoses are compared according to kibbutz category. The total number of events in all categories is represented as 100 percent. There were no major differences among the kibbutz categories.

As a further breakdown, Figure 7 presents data by category on clinic visits, episodes and laboratory diagnosis for the 12 important diseases out of the 24 included in the study (6 enteric and 6 control). Here, too, the rates for visits are presented as 100 percent. In the case of accidents, "laboratory confirmed" refers to such things as X-rays confirming fractures, etc.

In this study, some 91,000 clinic visits were recorded, which means a little less than one clinic visit recorded in the patient's file per year for the 24 diseases included in the study. It was not possible to obtain information on clinic visits other than those where the doctor saw the patients and made an entry in the patient's file. In the kibbutz clinic setup, numerous contacts were made with the kibbutz nurse without entry in to the patient's file. In some cases these visits were recorded in the nurse's daily log. In others no record was kept, while in some, nurses made entries in the patient's file. This variability in the quality of the morbidity data recorded must be taken into account in a retrospective study of this type. In this data set, the number of episodes is almost identical with the recorded number of visits, while it would be expected that the number of clinic visits would be significantly greater than the number of episodes. In addition, it was noted that follow-up visits after a visit to the physician were often handled by the nurses and went unrecorded.

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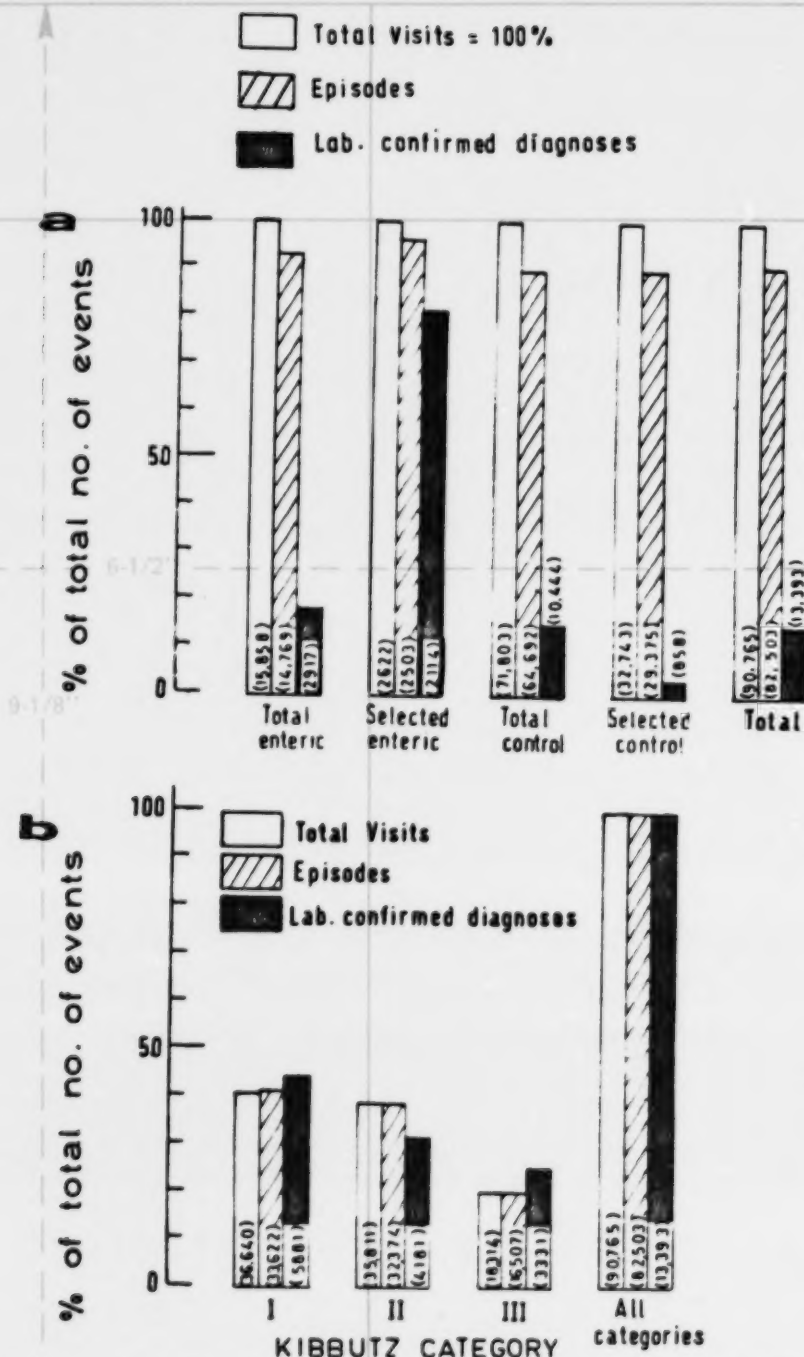


Figure 6. Comparison of number of clinic visits, episodes and laboratory confirmed diagnoses for the 24 diseases by grouping and by kibbutz categories for all ages. (Figures in columns are numbers of events.)

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Lab. Confirmed

Episodes

Visits = 100%

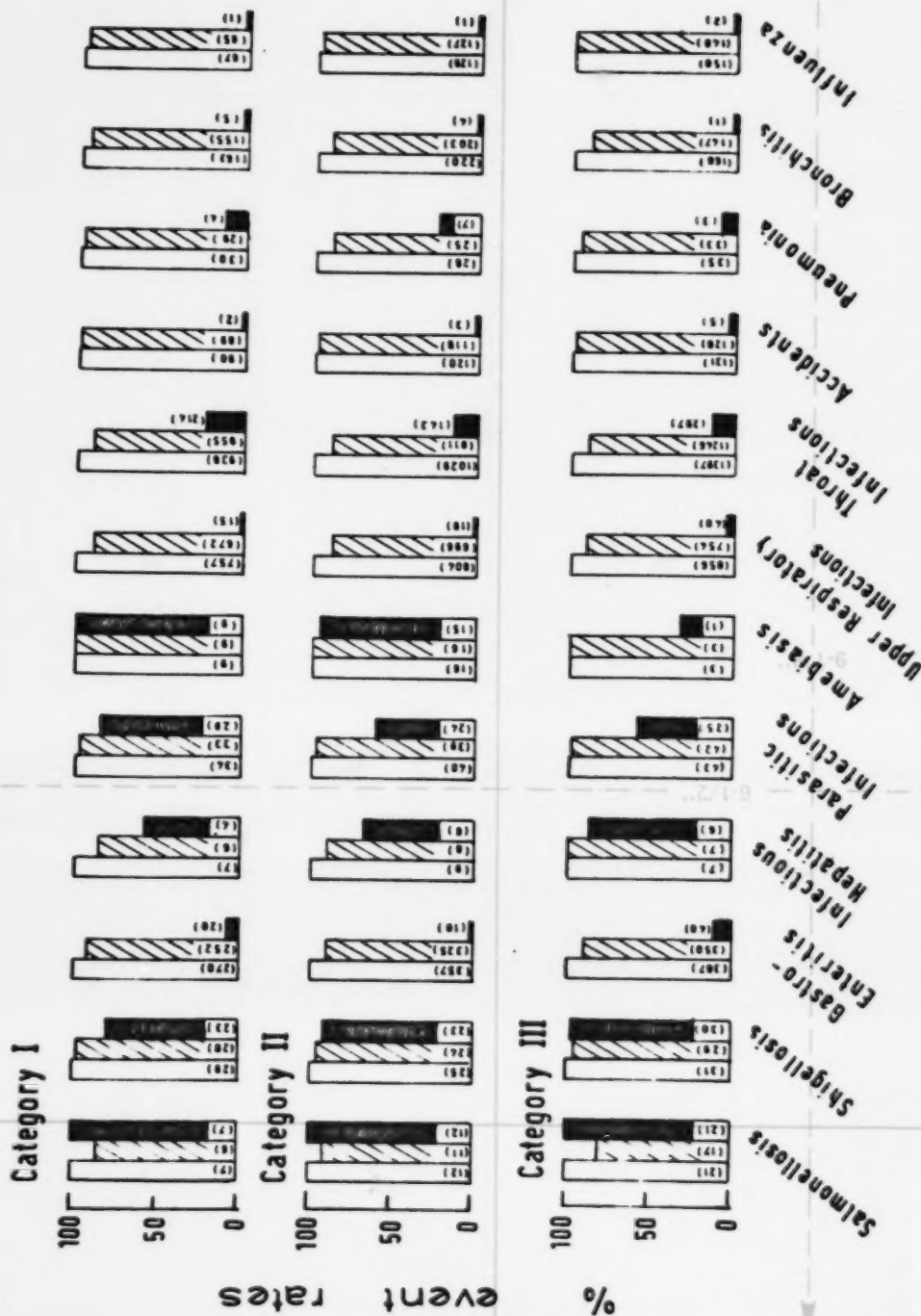


Figure 7. Comparison of rates for clinic visits, episodes and laboratory confirmed diagnoses for 12 diseases by kibbutz category. (Figures in columns are rates of events/1000 persons/year.)

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Distribution of Clinic Visits

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Figure 8 presents the distribution of the mean number of clinic visits/person/year for the 24 diseases for each kibbutz category. While it was not anticipated that a normal distribution pattern in such relatively small groups would be found, for purposes of rough comparison, means and standard deviations are presented. For all categories, the mean was 0.75 visits/person/year with a standard deviation of ± 0.35 . The mean for category I was 0.63 ± 0.31 for category II, 0.81 ± 0.40 and for category III, 0.91 ± 0.19 .

In category II, three kibbutzim had mean visits/person/year greater than 2 S.D. (Standard Deviations) but less than 3 S.D. These are the same three that appear as outliers in "All categories". All other kibbutzim fell within 2 S.D. of the mean. The influence of the outliers was examined in analysis of the data by inclusion and exclusion from specific calculations. This will be discussed later. There are three outliers in all categories.

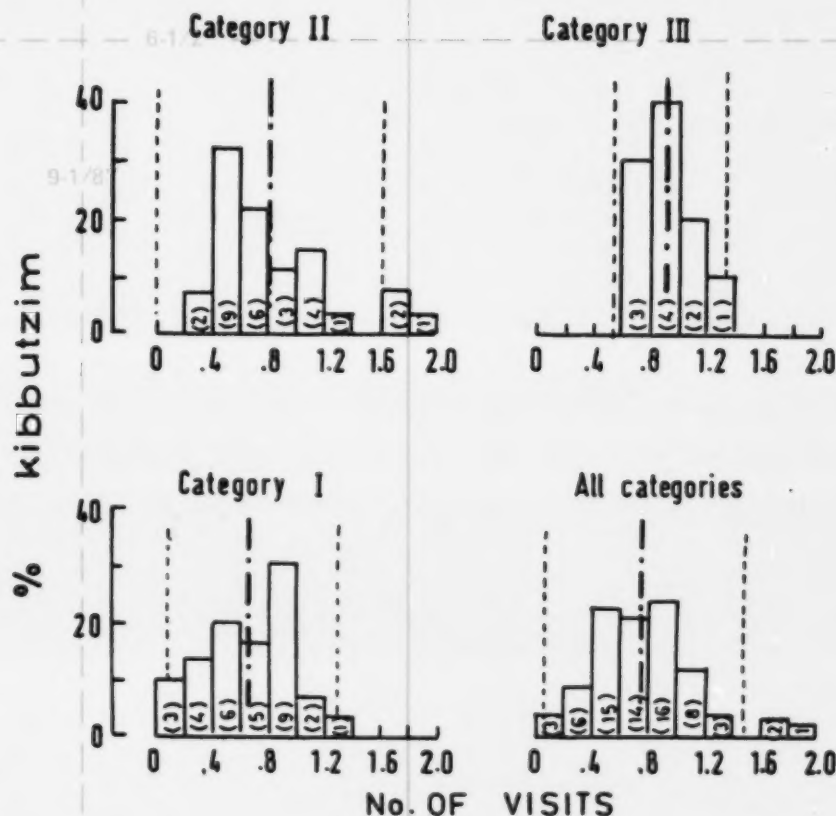


Figure 8: Distribution of clinic visits/person/year for the 24 diseases by category for all ages (figures in columns are numbers of kibbutzim).

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Figure 9 presents the distribution of the total number of visits/person/year for all symptoms and diseases recorded in the patient's file, by category for all ages. Here, too, means and standard deviations are presented for purposes of rough comparison. The average number of visits for all symptoms and diseases in all categories = 3.28/person/year with a standard deviation of ± 1.32 , while for such small numbers, normality tests were not felt to be appropriate, the distribution appears more or less normal with three outliers in all categories.

The mean in category I was 3.07 ± 1.41 ; in category II, 3.40 ± 1.23 and in III, 3.60 ± 1.13 .

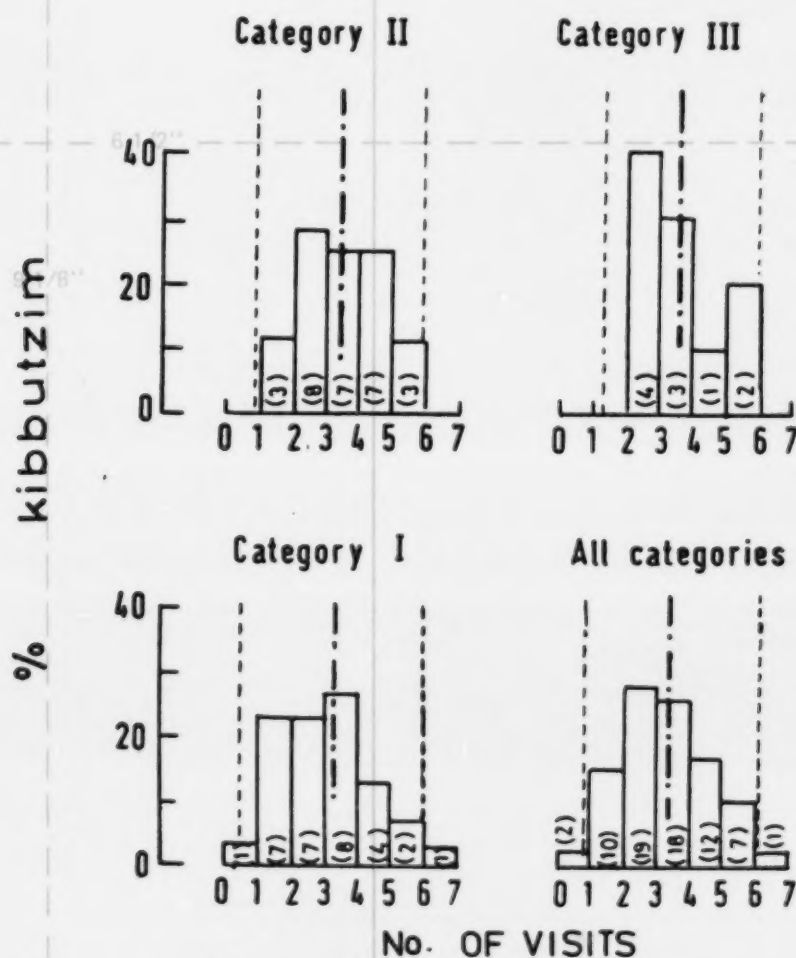


Figure 9: Distribution of total number of visits/person/year for all symptoms and diseases by category for all ages. (Figures in columns are numbers of kibbutzim.)

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There were differences in the mean rate of clinic visits/person/year in the three categories of kibbutzim, with category III showing the highest and category I the lowest. This was particularly evident in visits for the 24 study diseases, as shown in Figure 8, where category III had 44 percent more visits/person/year than in I, category III had only 12 percent more than category II, while category II had 29 percent more than I.

Outliers

From Figure 8 it may be observed that 3 kibbutzim in category II and one each in categories I and III may be considered outliers on the basis of distribution of clinic visits, since they are equal to or greater than 2 S.D. of the mean. Annual enteric and control disease rates for the three categories of kibbutzim were calculated in computer runs with and without the five outliers. The rates both with and without outliers were observed to be essentially the same. Based on this observation, the analysis of the data included the so-called outliers in order to maintain the sample size. The logistic and log linear models did, however, take into consideration the number of clinic visits at each kibbutz to provide a degree of control for deviations due to the number of visits recorded.

Reporting Factor: Adjustment of Disease Rates Based on Rate of Recorded Total Clinic Visits

One of the variables that had to be dealt with in this study was the variation in the recording of clinic visits in the different kibbutzim, which we have called the reporting factor. No direct information could be obtained on this in a retrospective study of this type. The rate of total recorded clinic visits for all symptoms and diseases for all ages as presented in Figure 9 was used as a proxy for developing a rough reporting factor. It was assumed, for this purpose, that the variations in the rate of total visits/person/year were predominantly affected by reporting practices rather than environmental causes. The mean number of visits/person/year for all such visits was 3.28, of which 0.75 visits/person/year were for the 24 control and enteric diseases. Only 18 percent of these, or .14 visits/person/year, were for the 12 included in the total enteric disease group. Thus, only about 4 percent of the total number of clinic visits for all diseases and symptoms were for the enteric diseases, potential candidates for influence by wastewater utilization practices.

A reporting factor for each kibbutz was calculated based on the mean rate of total clinic visits for all symptoms and diseases for all kibbutzim.

Figures 10 and 11 present the monthly variation in disease rates for the total 24 diseases, total control and total enteric disease groups for all ages, both adjusted by the reporting factor and non-adjusted, and for categories I and III combined, and II. The adjusted and non-adjusted variations in monthly rates were compared by observation and found to be essentially congruent within the categories.

In the logistic and log linear models, the reporting factor was taken into consideration as described in that section of the report.

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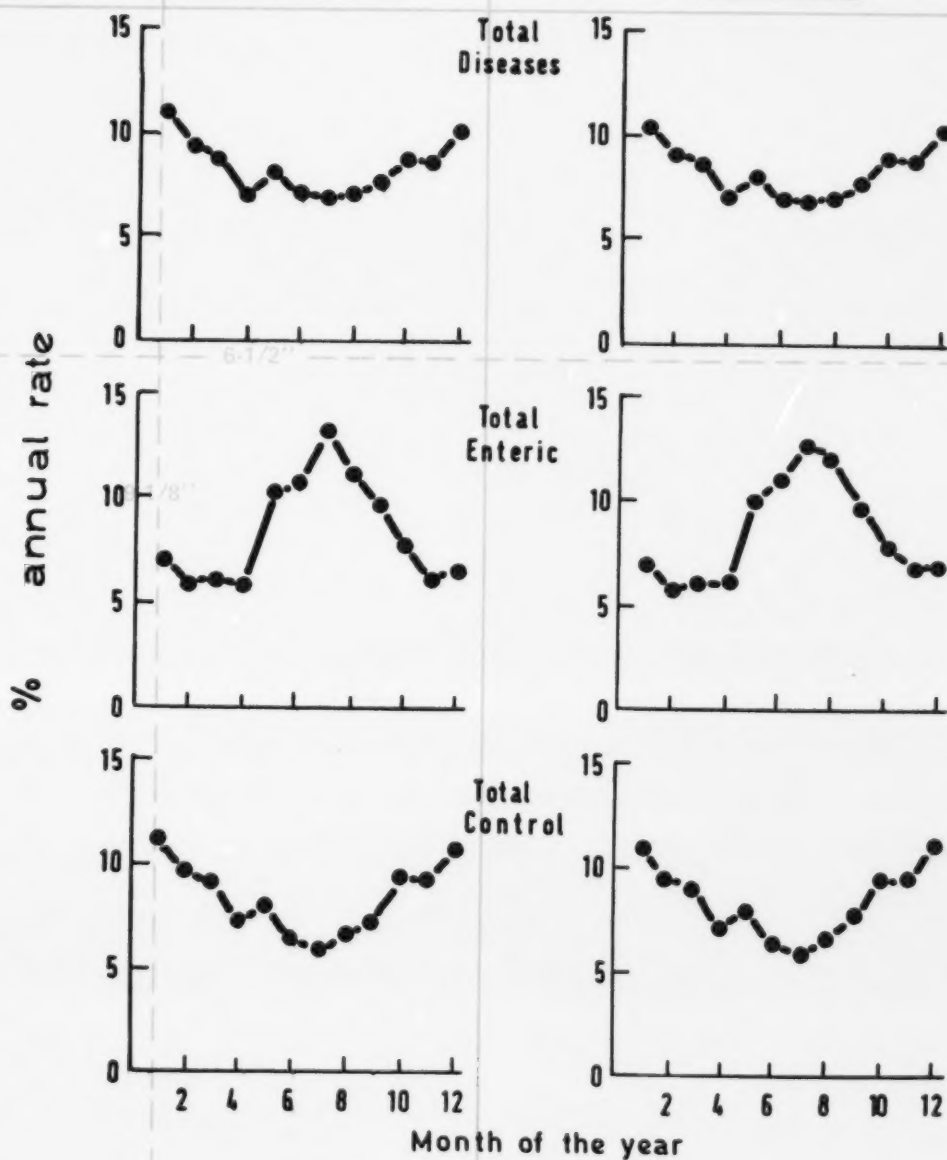


Figure 10. Disease rates adjusted by reporting factor: monthly disease rates for all ages in categories I and III combined.

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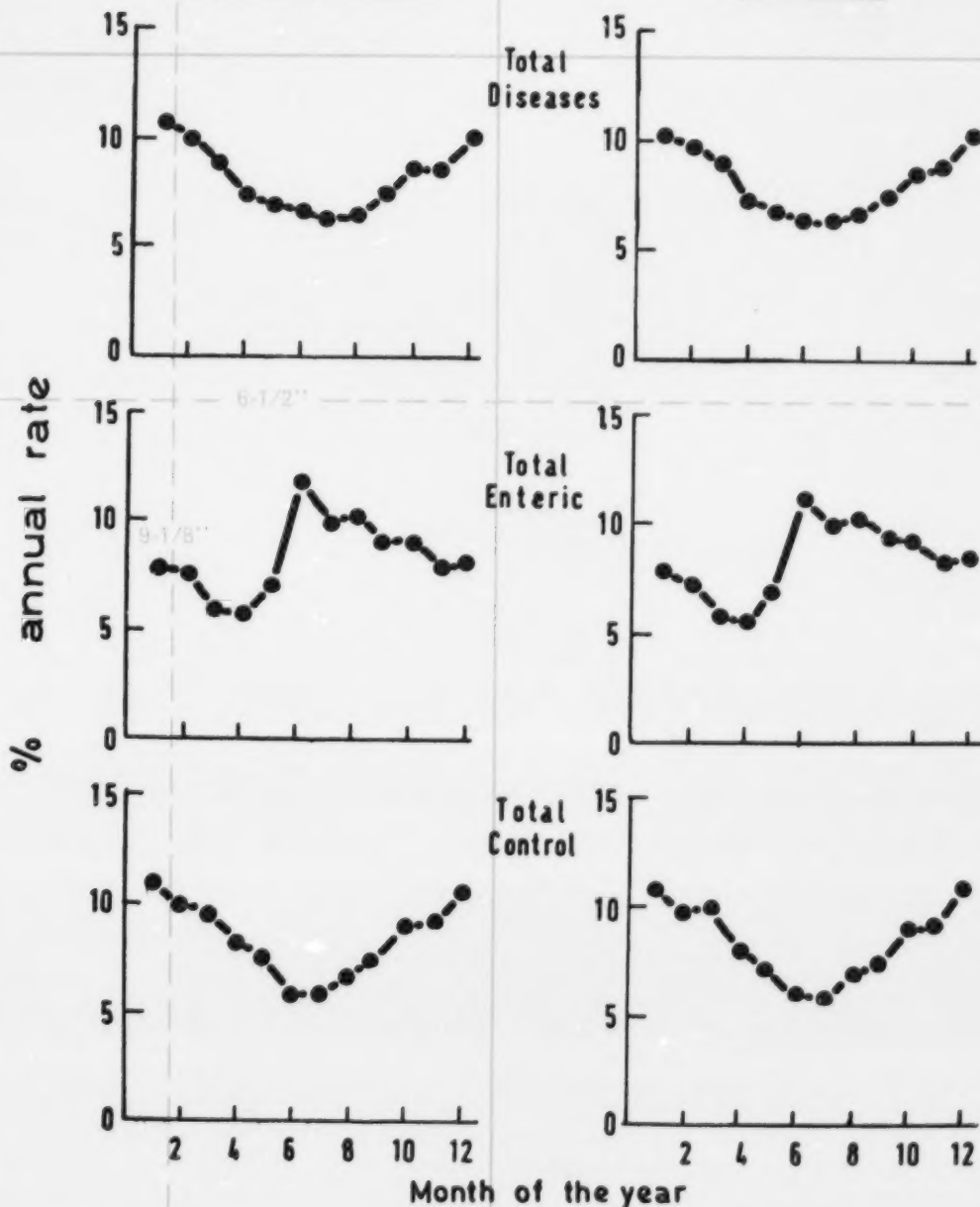


Figure 11. Disease rates adjusted by reporting factor: monthly disease rates for all ages in category II.

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Distribution of the Number of Clinic Visits for Individuals

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Figure 12 shows the nature of the distribution of the number of clinic visits made by individuals over the 4 year study period in the three categories of kibbutzim for total enteric (Figure 12a) and total control diseases (Figure 12b). Some seventy percent of the population in all 3 categories combined made no clinic visits for any of the enteric diseases during the 4 years of the study. The differences between the mean and individual categories was about ± 5 percent. About 29 percent made between 1-4 visits with about 1 percent having made more than 4 visits during the 4 year period. About 0.1 percent made 9 or more visits. There were only 5 individuals who made more than 3 visits per year for enteric diseases with one person visiting 16 times over 4 years or a mean of 4 visits per year.

No clustering of individuals with large numbers of multiple visits per year was found. It can be assumed that among the small number of individuals who made more than one clinic visit per year, many--if not most--made their repeat visits in connection with the same disease episode. Thus with the procedure for calculating episodes as used in this study, the number of individuals with more than one episode per year was expected to be much lower than 0.1 percent.

As for control diseases, it can be seen that for all categories combined some 32 percent of the individuals made no clinic visits for control diseases over the 4 year study period, with some 48 percent making between 1-4 visits. Six percent made 9 or more visits with 166 individuals making more than 4 visits per year for control diseases and 96 individuals making 5 or more visits per year.

As expected with the control disease category, which includes various respiratory diseases, a degree of clustering of individuals with a high number of multiple visits per year was found. However, here too, many of these visits were associated with the same episode, thus reducing the high number of visits for certain individuals considerably. Since the analysis was based primarily on episodes, the effect of this clustering was muted.

The statistical effects of this distribution pattern are discussed in the sections dealing with the log linear and logistic models.

As a further analysis of the question of the distribution of the number of clinic visits for control and enteric diseases, a cross tabulation was made between the number of individual visits for control disease or enteric disease by the same person.

The question under examination here, is whether persons who make frequent visits for control diseases, also make frequent visits for enteric diseases. This could possibly be associated with: a predisposition to illness in general; a predisposition to make clinic visits when ill; or the detection of an enteric disease during a visit for a control disease or vice versa.

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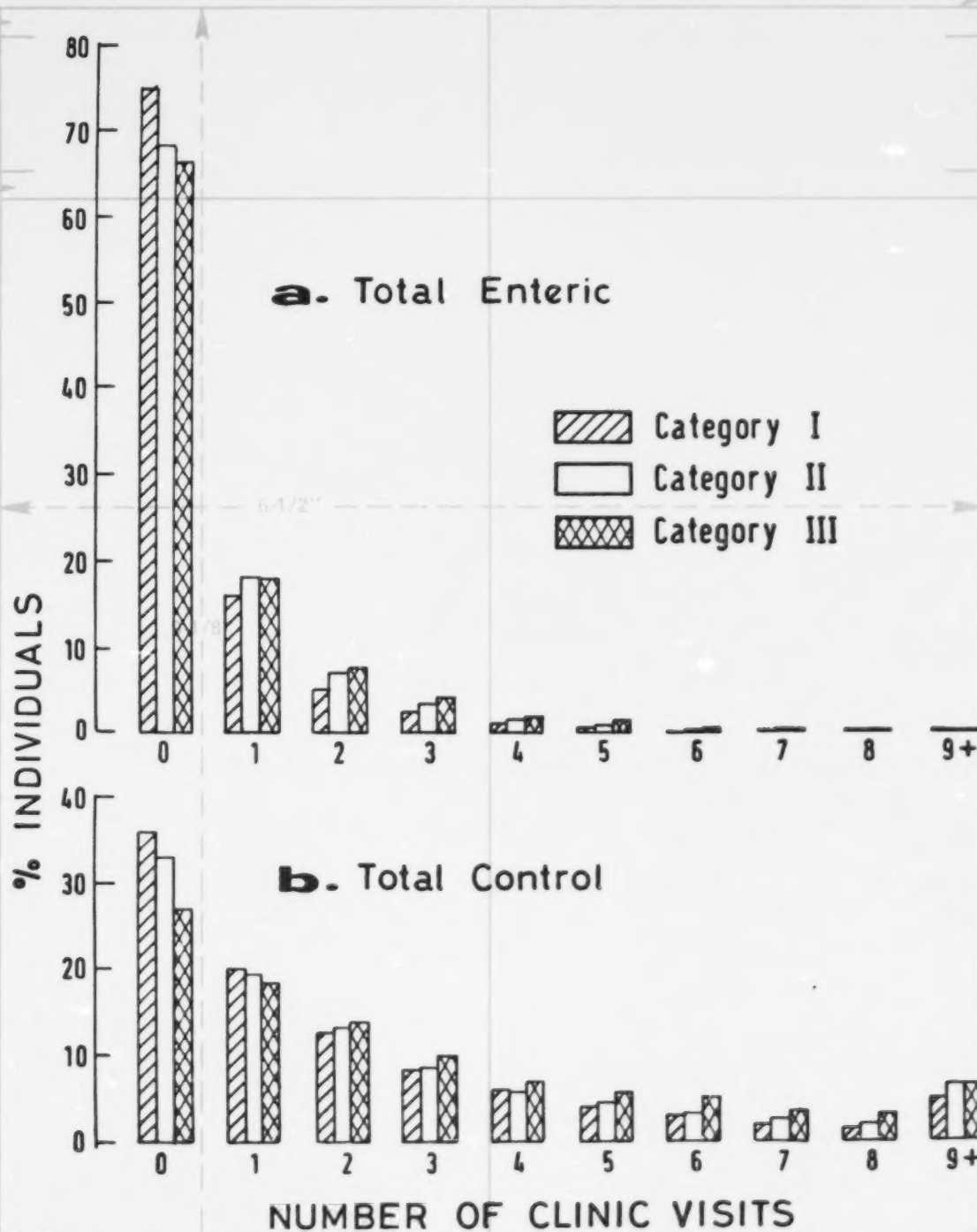


Figure 12. Distribution of the number of clinic visits during the four year study for individuals for enteric and control diseases by kibbutz category.

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Table 8 shows an abbreviated form of the cross tabulation with up to 4 visits for enteric diseases over a 4 year period against 8 visits for control. Five or more visits for total enteric, and 9 or more visits for total control are also shown in Table 8.

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TABLE 8. CROSS TABULATION BETWEEN VISITS FOR ENTERIC AND
CONTROL DISEASES BY THE SAME PERSON

All categories - all ages (percent of total population for 4 years)

No. Visits Enteric	0	1	2	3	4	5+	Total
No. Visits Control							
0	29.2	3.4	0.8	0.3	0.1	0	33.8
1	15.2	3.1	0.8	0.3	0.1	0	19.5
2	9.3	2.5	0.8	0.2	0.1	0.1	13.0
3	5.9	1.9	0.7	0.3	0.1	0	8.9
4	3.6	1.5	0.5	0.3	0.1	0.1	6.1
5	2.4	1.1	0.5	0.3	0.1	0.1	4.5
6	1.6	0.9	0.4	0.2	0.2	0.2	3.5
7	1.1	0.6	0.3	0.2	0.1	0.2	2.5
8	0.7	0.5	0.2	0.2	0.1	0.1	1.8
9+	1.8	1.6	1.2	0.7	0.4	0.7	6.4
TOTAL:	70.8	17.1	6.2	3.0	1.4	1.5	100.0

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From this table it was observable that some 29 percent of the population made no clinic visit for either enteric or control disease categories, as defined in this study. Of the 71 percent who made no visit for enteric diseases, 41.6 percent of them made one or more visits for control diseases. Thirty-four percent made no visit for control diseases and of them, 4.5 percent made one or more visits for enteric diseases.

Disease Rates in Irrigation vs. Non-Irrigation Periods

Enteric and Control Diseases--

This section presents the crude rates of enteric and control diseases for effluent utilizing kibbutzim (I and III) vs. non-effluent utilizing kibbutzim (II) as well as for categories I, II and III separately. The rates presented were calculated for different time periods, age groups and from a number of different aspects. This presentation is for orientation purposes prior to the statistical analysis using the logistic and log linear models; thus no statistical tests were applied in this section.

The rates presented are as episodes/1000 persons/year as defined in Section 4, and relate to the specific time periods as defined in that Section. The rates are always adjusted to a 12-month basis except where noted. For example, if the rate for the 4-month summer period was given for a specific age group in a specific kibbutz category, all the episodes of the disease group were counted and divided by the total number of months, i.e. 16 months based on 4 summer months per year for 4 years, giving the mean monthly rate. This value was then multiplied by 12 to produce an annual rate for comparative purposes.

The rates are presented in the form of histograms (figs. 13-20) in which the rate for category II (non-effluent utilization) is presented as 100 percent. The number in the column is the calculated rate of episodes/1000 persons/year. The other categories are presented as a percent of category II. The histograms thus compare the rates in each category as a ratio of category II.

The age "0" represents the period from birth to the day before one year of age. Likewise "1" represents the period from the first birthday until one day before the second birthday, and so on.

In Figure 13, a comparison of total enteric and total control disease episodes during the irrigation and non-irrigation periods in kibbutz categories I + III vs. II is presented for various age groups. By inspection, there was a small excess in I + III in the 0-1 age group with a small reverse above that age in the irrigation period (13b). During the non-irrigation period, there was also a small excess in the 0-1 age group with a larger reverse effect for ages 5 years and above (13a). Figure 14 presents total control disease as in Figure 13. No difference in rates appears in any age group in either irrigation or non-irrigation periods. Figure 15 is similar to Figures 13 and 14 but compares categories I, II and III separately.

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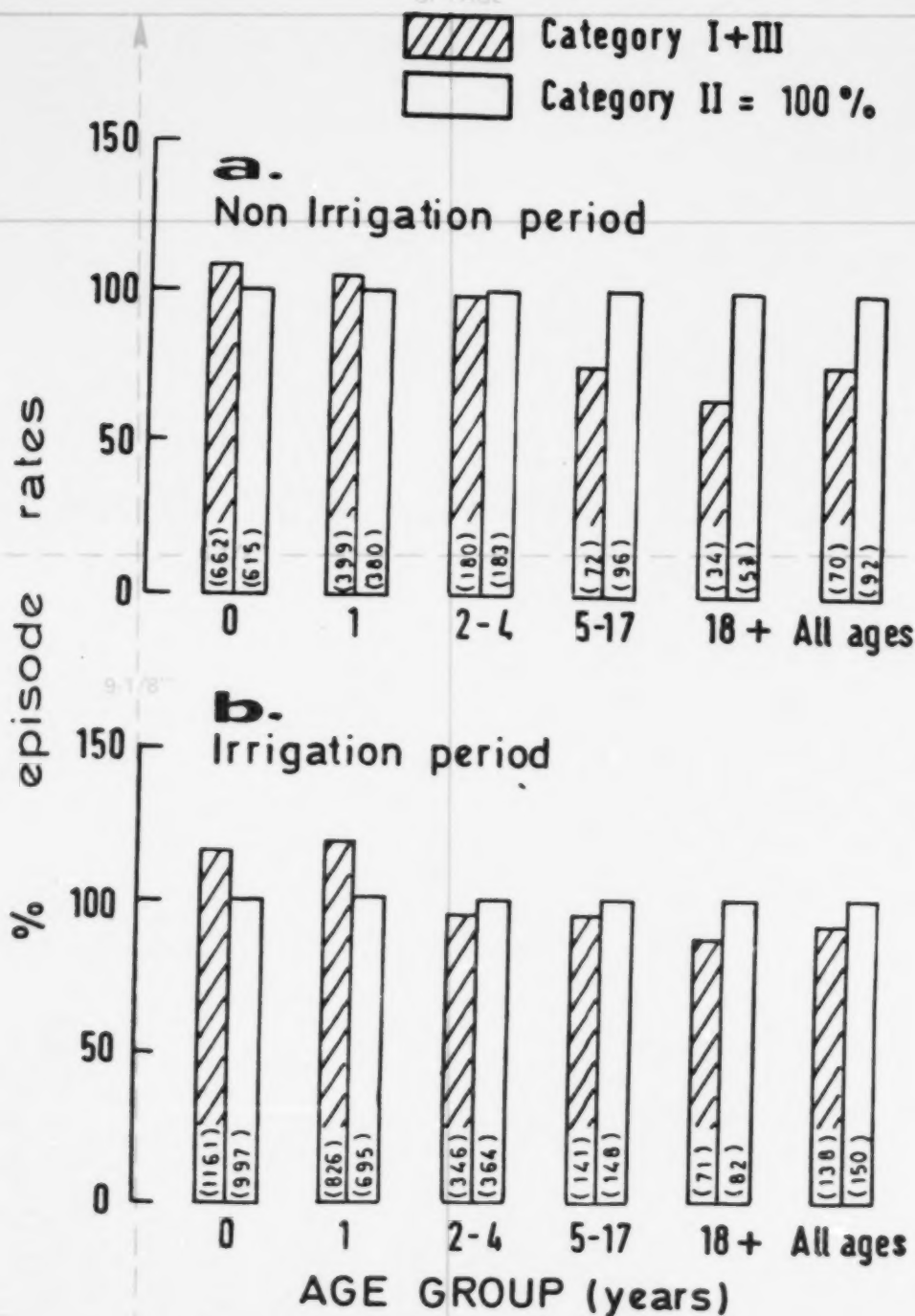


Figure 13. Comparison of rates of episodes of total enteric disease in effluent (I and III) and non-effluent (II) utilizing kibbutzim in irrigation and non-irrigation periods by age group. (Figures in columns are rates of episodes/1000 persons/year.)

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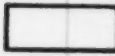
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 Category I + III
 Category II = 100 %

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Non Irrigation period

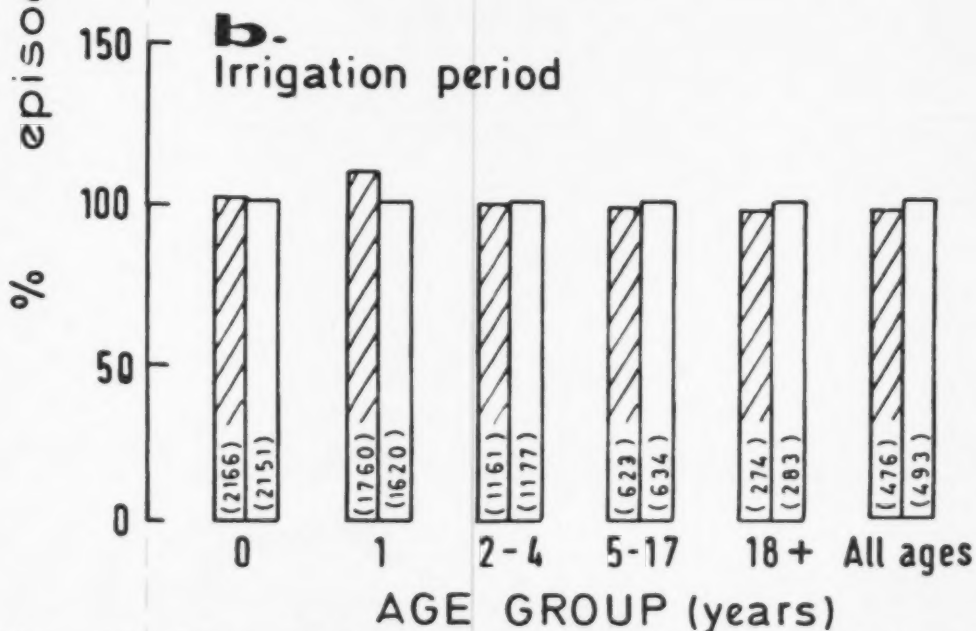
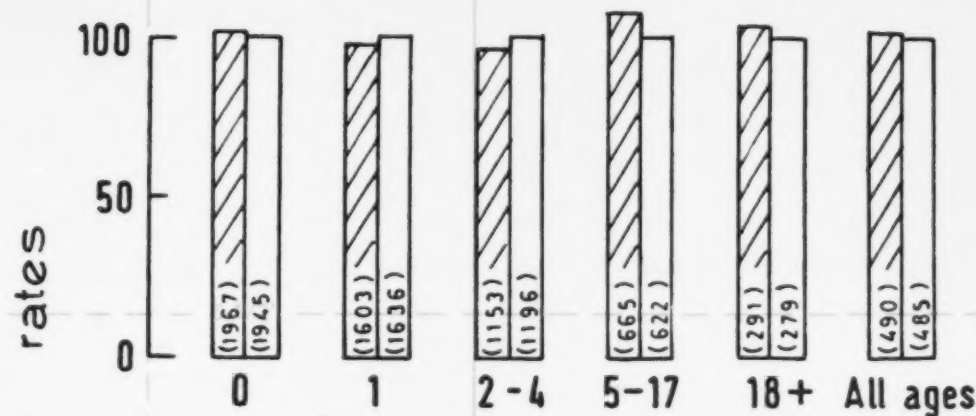


Figure 14. Comparison of rates of episodes of total control diseases in effluent (I and III) and non-effluent (II) utilizing kibbutzim in irrigation and non-irrigation periods by age group. (Figures in columns are rates of episodes/1000 persons/year.)

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From Figure 15a, it would appear that the enteric disease rates in category I were similar to or slightly lower than, category II for each age group separately and for all ages combined during the irrigation period, while the enteric disease rates in III are greater than II in each age group and for all ages. In Figure 15b, I was lower than II while II was higher in the lower age groups, lower in the age groups of 5 and above and about the same for all ages combined. In Figure 15c and 15d, the rates for the control diseases for the three categories were generally similar to each other with a few deviations.

Specific Enteric Diseases - Salmonellosis and Shigellosis--

The data presented in the previous figures, for total enteric disease, includes all 12 enteric diseases, some of which may not necessarily be strictly associated with transmission by exposure to wastewater. As a refinement, we selected the two most prevalent enteric diseases--salmonellosis and shigellosis--which could generally be considered as definitely associated with exposure to wastewater. This allows us to determine if either of these serves as a more specific index of the risks associated with environmental exposure to wastewater. These two diseases were included in the earlier retrospective study (Katznelson et al. 1976) in addition to infectious hepatitis and typhoid fever. This project could not analyse the latter two diseases due to the very small number of episodes recorded.

Figure 16 compares the rates of salmonellosis and shigellosis during the irrigation period in categories I and III vs. II. In Figure 16a, it appears that there were no differences, except in the 5-17 age group, where I and III were lower than II. The rates in this age group were very low and the apparent difference may not be meaningful. In Figure 16b, there appears to be an excess of shigellosis in all age groups except in 2-4 years.

Figure 17 compares the same two diseases for categories I, II and III separately. In Figure 17a, there appeared to be an excess of salmonellosis in category III over II, in ages 0-4 and all ages, while category I is lower than II in all age groups except 18+. The rates in this age group were very low. In Figure 17b, shigellosis rates appear to be greater in I and III than II in all age groups except 2-4. In age group 5-17, the rates in category I were greater than category II and III.

Comparison by Geographical Regions--

The ten kibbutzim in category III are located in the northern region. This region has a number of unique characteristics including higher rainfall rates and more plentiful natural water supplies which lead to shorter irrigation periods than the central and southern regions. Drinking water is more often drawn from polluted surface sources in this region. In order to determine whether geographical location had any effect on disease rates, an analysis by regions was made.

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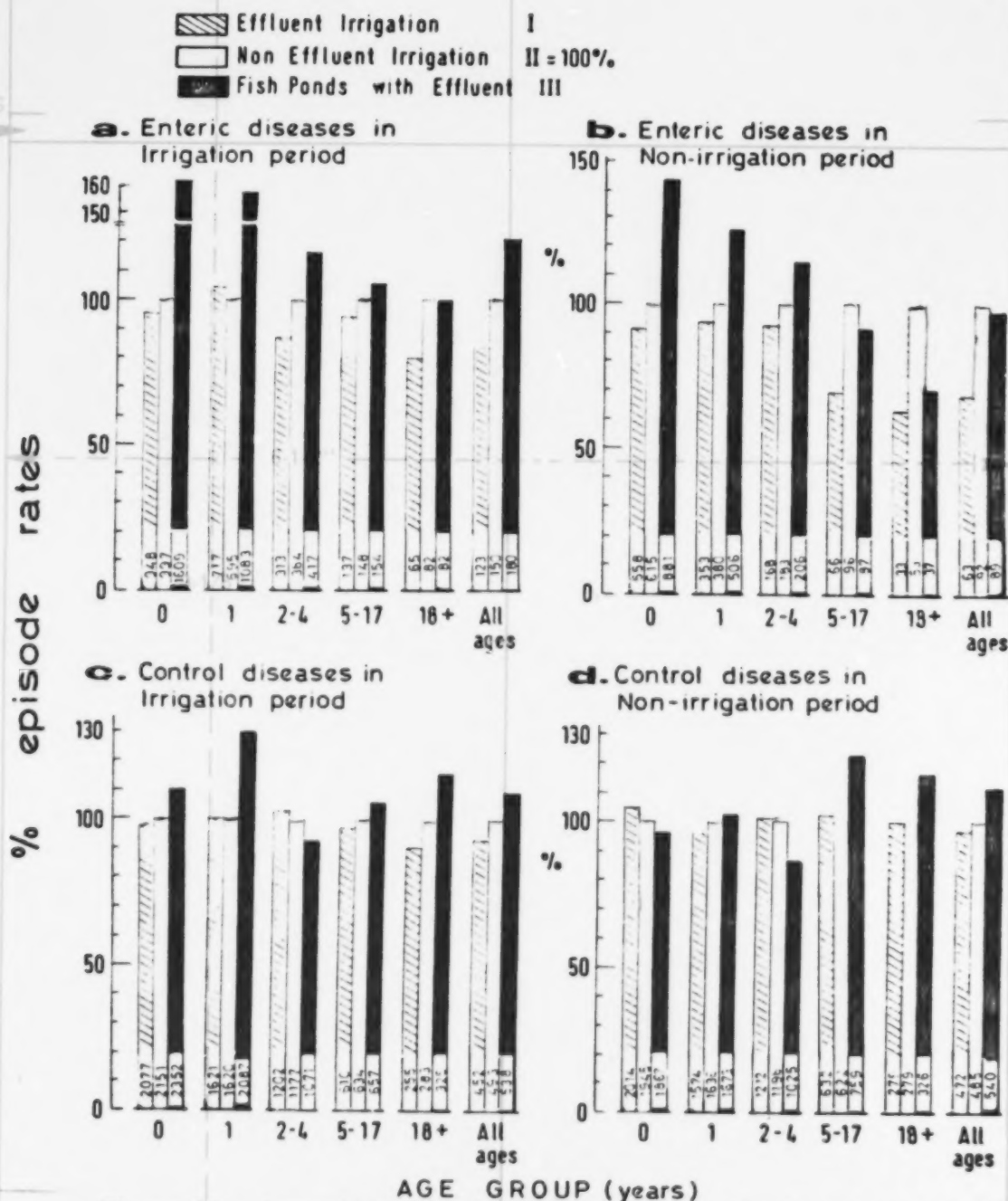


Figure 15. Comparison of rates of episodes of enteric and control disease in irrigation and non-irrigation periods by category and age group. (Figures in columns are rates of episodes/1000 persons/year.)

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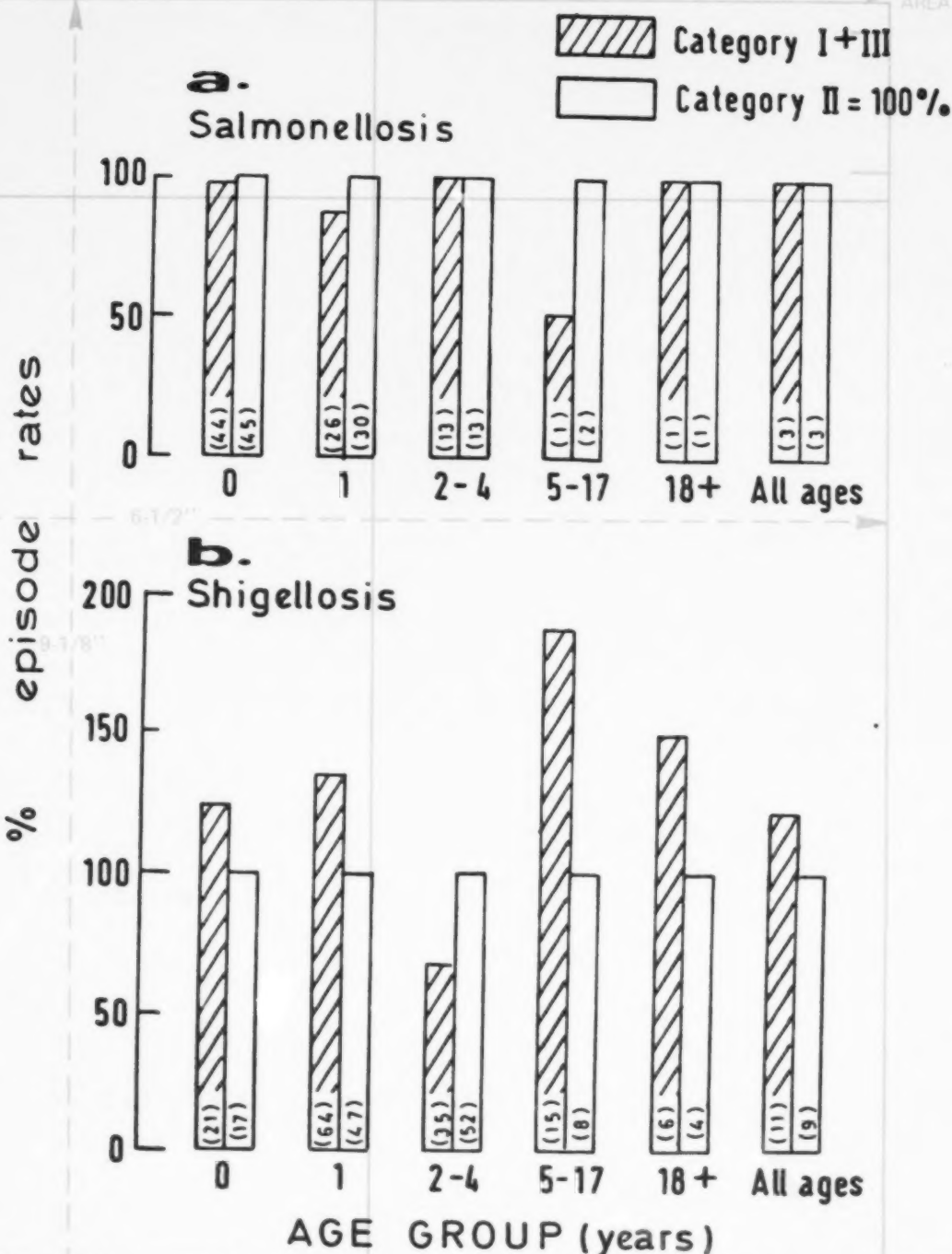


Figure 16. Comparison of rates of episodes of salmonellosis and shigellosis in effluent (I and III) and non-effluent (II) utilizing kibbutzim in irrigation period by age group. (Figures in columns are rates of episodes/1000 persons/year.)

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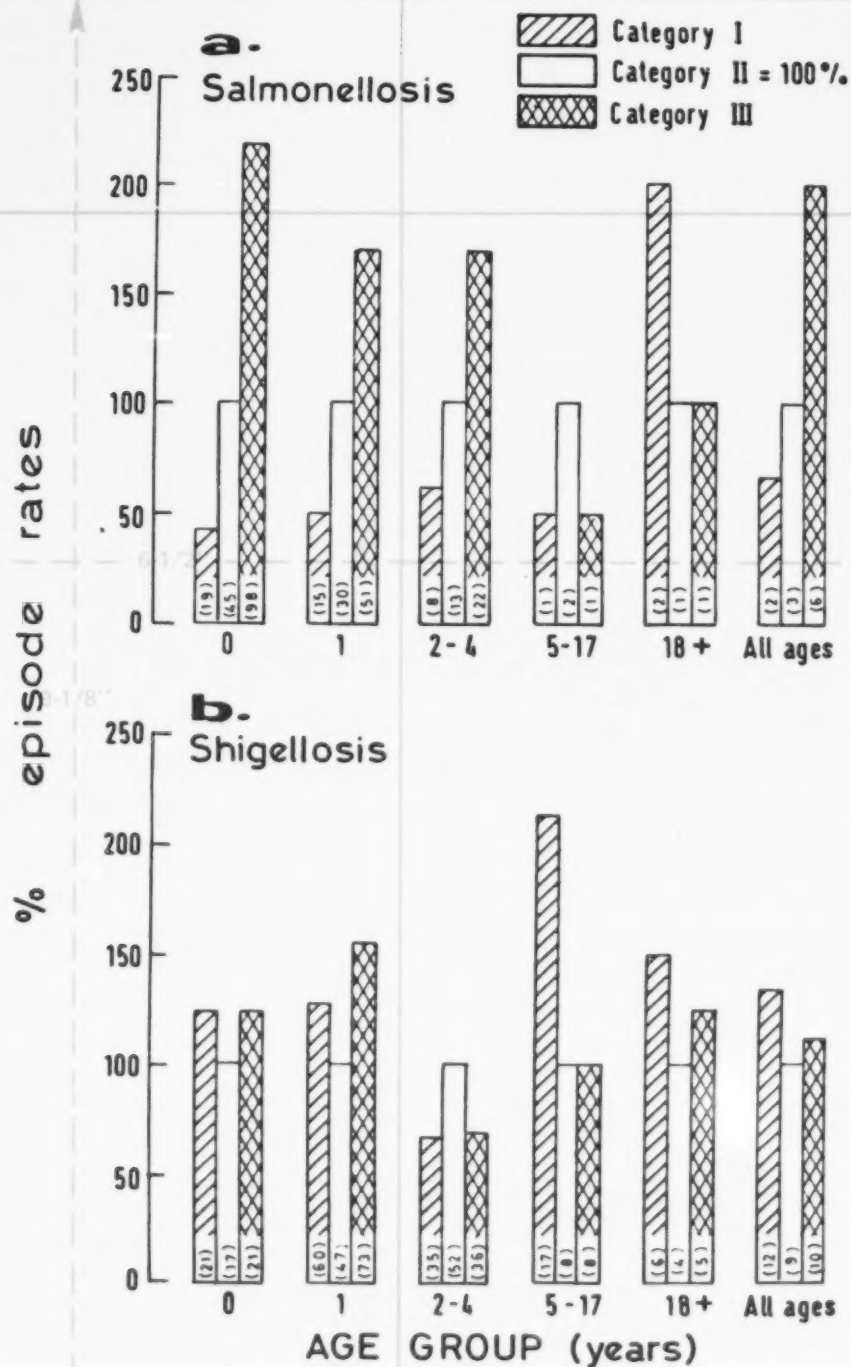


Figure 17. Comparison of rates of episodes of salmonellosis and shigellosis in kibbutz categories I, II and III in irrigation period by age group. (Figures in columns are rates of episodes/1000 persons/year.)

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Figure 18 presents the enteric disease rates by regions during the irrigation period. The northern region included 8 of the 10 kibbutzim in category III with a total population of 3750. Two kibbutzim of category III were not included in this run due to a computer format error detected at a stage too late to correct. Category I included 10 of the 30 with a population of 4953, while II included 12 of the 28 with a population of 5341.

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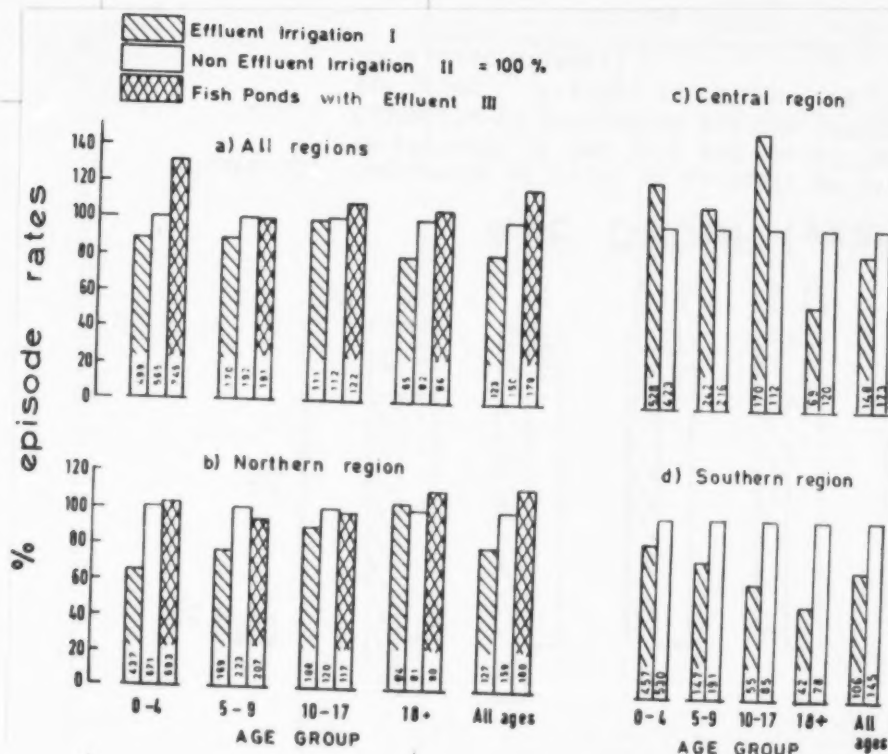


Figure 18. Comparison of rates of episodes of total enteric disease by geographic region, by kibbutz category and by age group. (Figures in columns are rates of episodes/1000 persons/year.)

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The central region included 9 in category I, with a population of 4321 and 6 in category II, with a population of 1584. The southern region includes 11 in category I, with a population of 3871 and 10 in category II, with a population of 3746 (see Table 9).

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TABLE 9. DISTRIBUTION OF KIBBUTZIM POPULATION BY REGIONS AND BY CATEGORIES

Category	Region	No. of Kibbutzim	Total Population
I	North	10	4953
	Center	9	4321
	South	11	3871
II	North	12	5341
	Center	6	1584
	South	10	3746
III	North	8	3750
	Center	-	-
	South	-	-

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It appears from Figure 18b that there was no excess of enteric diseases in category III over II in the age group 0-4 in the northern region, as appeared in the same age group in all regions combined (Figure 18a); however, a slight excess in III over II remained in the 18+ age group and all ages combined. The central and southern regions include only kibbutzim from categories I and II. In the central region (Figure 18c), I was greater than II in the age groups up to 17 years, and lower in 18+ and all ages combined, while in the southern region I was lower than II in all age groups. This presentation suggests that the excess shown in III over II in all regions combined may be associated with some yet to be determined geographical factor in the Northern Region, since all of category III were clustered there. It also shows that differences exist between the southern and central regions.

Figure 19 compares the total enteric and total control disease rates in kibbutz categories I and II by geographical regions. Category III is excluded in this presentation, since all kibbutzim in this category were located only in the northern region. The disease rates in the first column of the histogram of each category represent the rate of all regions combined and were presented as 100 percent. No consistent pattern of regional difference was observed. The southern region showed lower rates than the other regions for enteric diseases in all ages and 0-4 in category II, and the central region in category II was lower for total enteric diseases in 0-4. Enteric disease in category I is lower in 0-4 and all ages. This may be associated with the generally longer irrigation period (9.3 months/year as compared to 7.6 months/year for all regions) which includes both the summer high and winter low portion of the enteric disease annual cycle.

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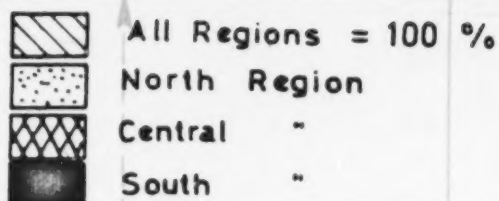
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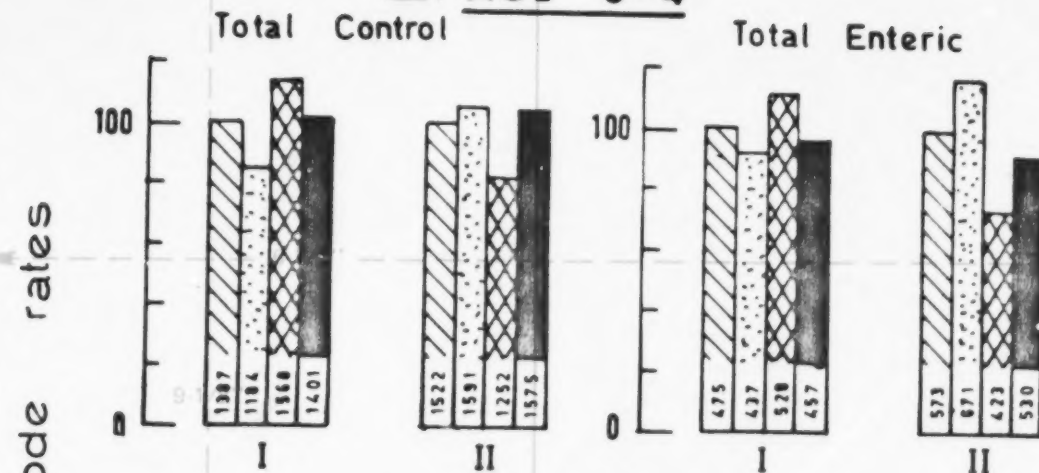
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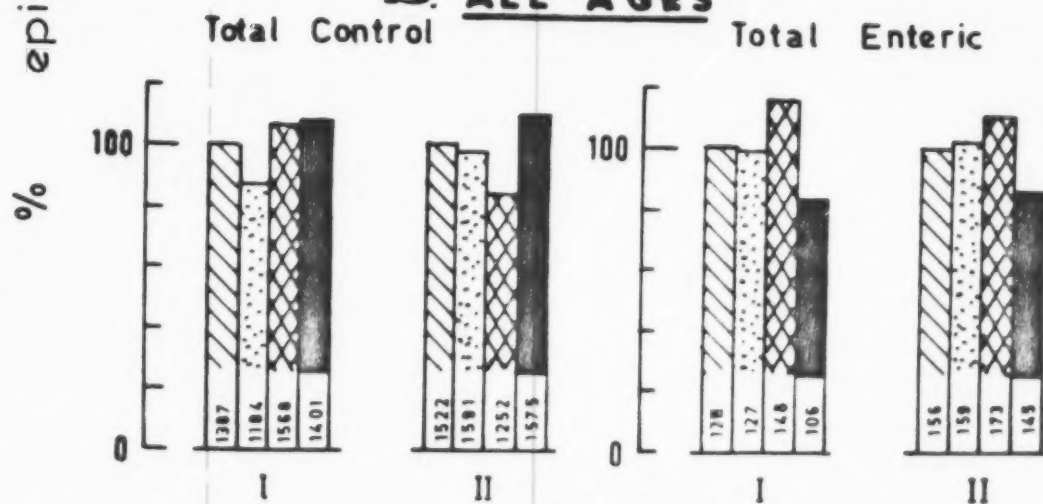
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a. AGE 0-4



b. ALL AGES



CATEGORIES

Figure 19. Comparison of rates of episodes of total enteric and total control disease rates within category I and II by geographical region during irrigation period. (Figures in columns are rates of episodes/1000 persons/year.)

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Comparison of Disease Rates in Summer vs. Winter

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Figure 20 presents a comparison of total enteric and total control disease rates in categories I, II and III during two defined periods of 4 months each. The months of May to August were called Summer, and November to February were called Winter. In the previous analysis, the irrigation period was based on the actual months of irrigation for each kibbutz separately. Most kibbutzim irrigated between May to October, with the majority concentrating their irrigation in May to August. However, 14 kibbutzim reported irrigating for all 12 months. Thus the calculated disease rate for the irrigation period varied between kibbutzim, with some including only summer months during the normal peak enteric disease period while others were based on 10-12 months, including both high and low enteric disease periods. In order to overcome the possible spurious effect on enteric disease rates due to varying lengths of irrigation periods, fixed four-month periods were compared.

In Figure 20, it appeared that category I had lower enteric disease rates than II in both summer and winter periods in both "0-4" and "all ages". It appeared that category III had higher enteric disease rates than II in "0-4" in both summer and winter, and in "all ages" in summer, with winter rates approximately equal. The same trend appeared for the control diseases.

The apparent excess of enteric diseases in category III over II and I remained in the summer-winter form of analysis as it did with the irrigation period, previously shown.

Food Poisoning and Influenza

There were 24 individual episodes of food poisoning recorded in the 68 kibbutz clinic files, but only 2 were laboratory confirmed. Cases of food poisoning were usually not recorded in clinic files. These 24 individuals were divided among categories as follows: category I--8; category II--15; category III--1.

Influenza was excluded from the total control and total enteric diseases categories because a case recorded as clinical influenza might be associated with an enteric virus type. The total number of recorded episodes of influenza was 3,018. According to their categories, they divide as: category I--880; category II--1400; category III--738. Figures 25e and 26c show the annual cycle of influenza by category I, II and I + III combined for kibbutzim irrigating from April to October only, for all ages. No further analysis of this disease was made.

Annual Cycle of Diseases in Effluent and Non-Effluent Irrigation Kibbutzim

General Annual Cycles--

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In this section the annual disease cycle for various disease groups is presented. In Figures 21 to 25, the monthly disease rate, as episodes per 1000 persons/month, was presented as a percent of the annual rate for the

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Effluent I
Non Effluent II = 100 %
Fish Pond with Effluent III

Summer Winter

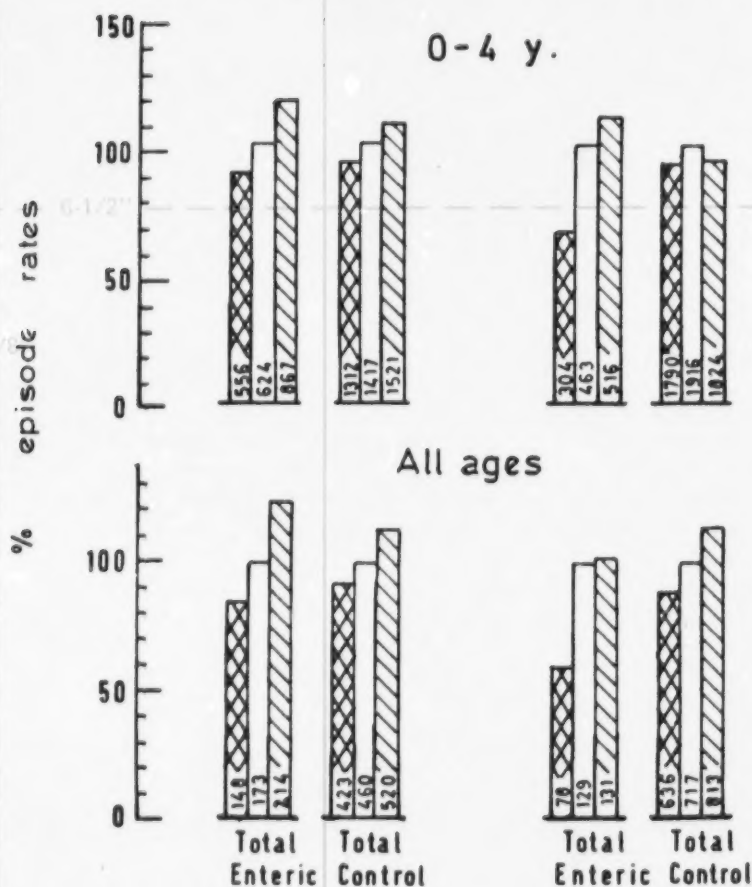


Figure 20. Comparison of rates of episodes of total enteric and total control diseases during summer (May - August) and winter (November - February) by category and age group. (Figures in columns are rates of episodes/1000 persons/year.)

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specific age and kibbutz category. This analysis was designed to detect if there were any observable differences in the disease pattern over the yearly cycle associated with different wastewater utilization patterns even if such differences did not appear in overall means for defined irrigation periods.

Figure 21 shows the annual disease cycle for total enteric and total control diseases in all 3 kibbutz categories combined in the 0-4 (21a) and all ages group (21b). This figure illustrates the known pattern of enteric disease cycles in kibbutzim, with a rapid increase in rates starting in May, a peak in July, dropping to a low level in November through April. This pattern holds for both 0-4 and all ages. The control diseases show the known inverse pattern for predominantly respiratory diseases, with a peak in December and January and a low in July. The annual rate for enteric disease in the three categories in the 0-4 age group was 465 episodes/ 1000 persons/ year, with a rate of 121 for all ages. For total control diseases, the annual rate for the three categories in the 0-4 age group was 1548 episodes/ 1000 persons/year, with a rate of 548 for all ages.

Annual Cycles for Enteric and Control Diseases between categories I and II--

For this analysis, we have looked at the annual disease cycle in the kibbutzim of category I and II practicing irrigation at different periods. Figure 22a shows total enteric disease rates for all ages and for all kibbutzim in categories I and II, regardless of irrigation period. The annual enteric disease rate in I was 102 episodes/1000 persons/year, with a rate of 124 for II. It was noted that category I rates were proportionately higher than II during May, July and August and proportionately lower from October through February. This suggested the hypothesis that there was a relative increase in enteric disease rates in category I immediately after the onset of wastewater irrigation in the early spring, which led to relatively lower rates of infection in the fall and winter months. In order to get information regarding this hypothesis, we compared separately those kibbutzim which irrigated during the months of April through October exclusively (Figure 22b), and those irrigating through the entire 12 months per year (22c). The remaining kibbutzim are presented in Figure 22d.

In Figure 22b, the annual enteric disease rate for 13 kibbutzim of category I was 110, and for the 12 kibbutzim in category II was 109. In this figure, the excess of enteric disease rates in category I over II in May through July was even more clear-cut than that seen in all kibbutzim (22a). The relatively lower rates of enteric disease in I as compared to II in September through April is clearly observed. In this case (22b), the excess of enteric disease in I vs. II in Spring is absolute and not merely relative, since the annual enteric disease rates for both categories were equal. The same holds for the deficit in the winter.

In 22c for kibbutzim irrigating all year long, the annual enteric disease rate for the 7 kibbutzim of I was 88, and for the 6 kibbutzim of II was 124. Here, no obvious difference in seasonal patterns was discerned. The same was true for the remaining kibbutzim, shown in 22d. The rate for the 16 of category I was 93, with a rate of 138 for the 12 kibbutzim of category II.

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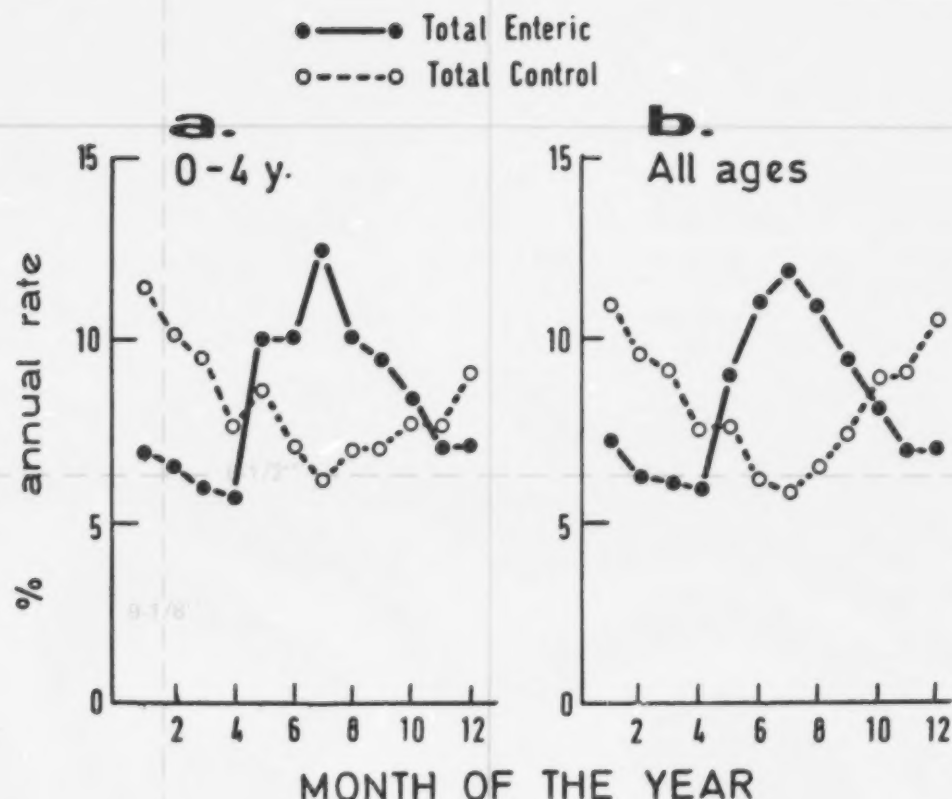


Figure 21. Annual cycles for total enteric and total control diseases in all kibbutz categories (I, II and III) for 0-4 and all ages.

The annual disease cycle pattern for the 0-4 age group (not presented) was observed to be essentially identical as that for "all ages". Here also, the annual rate for enteric diseases in the group irrigating in April-October was almost equal, with a rate of 433 episodes/1000 persons/year in category I vs. 423 for category II.

Figure 23 shows the annual cycle of total control diseases in all ages for the same groupings of kibbutzim by irrigation period for categories I and II as in Figure 22. The pattern of the annual disease cycle for control diseases was observed to be essentially identical for categories I and II in all groupings of kibbutzim, regardless of irrigation period. When the graphs of Figure 23 a,b,c and d were compared with each other, no essential differences in annual disease cycle patterns were observed. This suggests that the diseases selected for the total control diseases classification were not observably associated with wastewater utilization patterns or varying irrigation periods.

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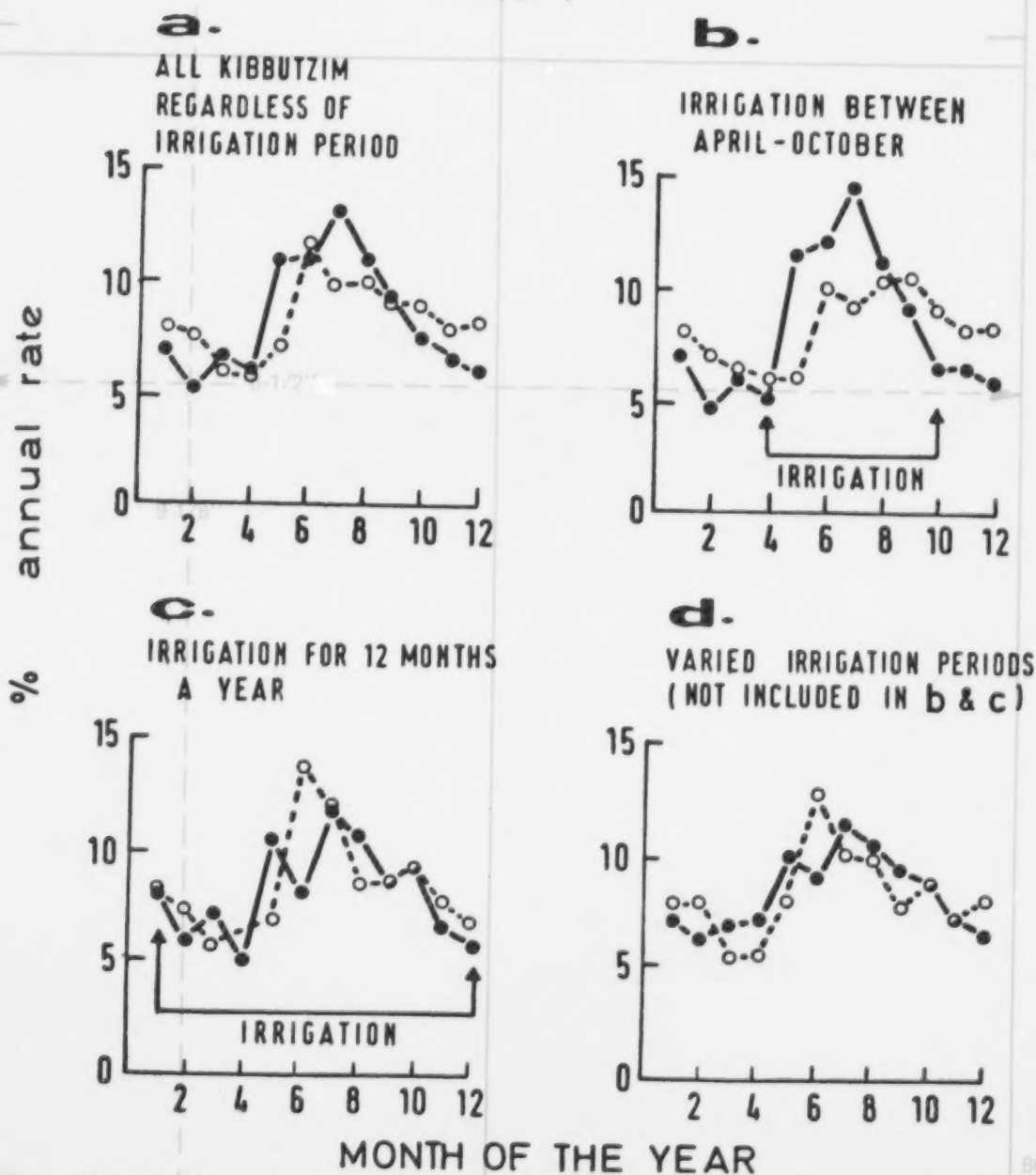


Figure 22. Annual cycle for total enteric diseases in kibbutzim irrigating during different periods with effluent (I) and non-effluent (II) - all ages.

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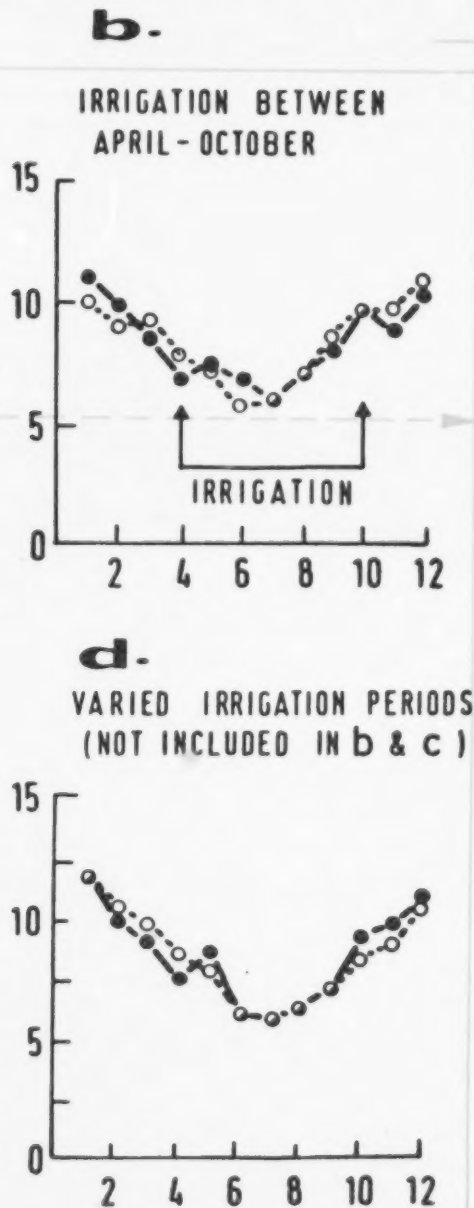
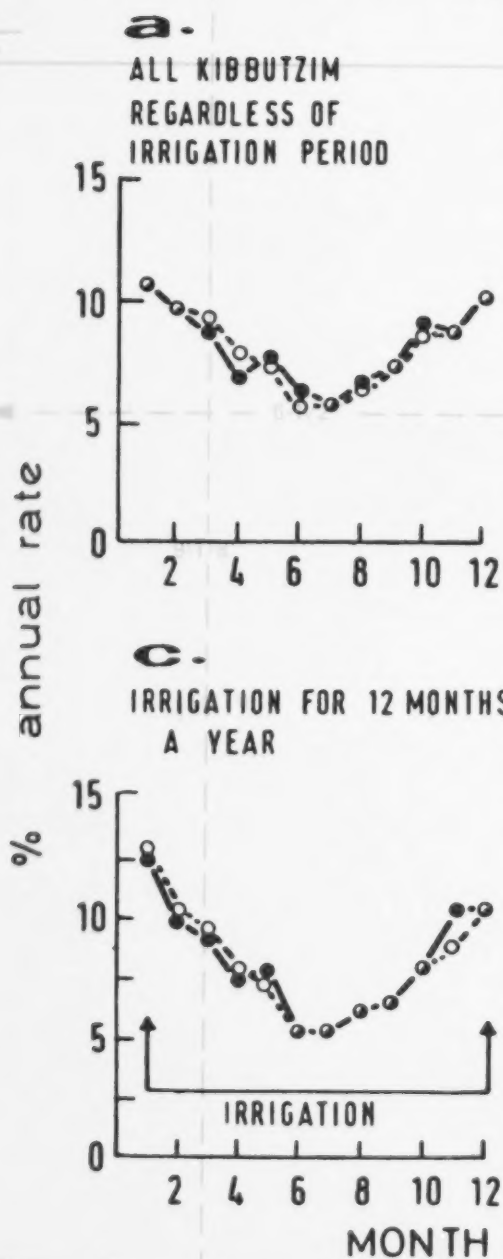


Figure 23. Annual cycle for total control diseases in kibbutzim irrigating during different periods with effluent (I) and non-effluent (II) - all ages.

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The annual rate of total control diseases for all kibbutzim as shown in 23a was 518 episodes/1000 persons/year in category I and was 526 in II. For Figure 23b, the rates were: I--523; II--451. For Figure 23c, rates were: I--553; II--597. The remaining group, as shown in Figure 23d, had a rate of 512 for I, and 602 for II. The difference in annual control disease rates between categories I and II remains unexplained.

Observation of the graphs for total control diseases for the 0-4 age group did not contradict the patterns shown in Figure 23.

Annual Cycles for III vs. II--

Figure 24 compares the annual cycle for total control and total enteric diseases in all kibbutzim of category III vs. II, regardless of irrigation period. Irrigation period is not connected with wastewater usage patterns in fish ponds. In category III kibbutzim, the use of wastewater as fish pond feed water was usually for the entire year, except for periods of pond cleaning and start-up. Figure 24a for enteric diseases, indicates that there was an observable relative excess in July-September in category III over II. The annual rates in III were 165 episodes/1000 persons/year, as compared to 124 for category II. Thus, there was also an excess of enteric disease in III over II on an annual basis. Figure 24b presents total control diseases which were observed to be similar in II and III. The annual rate for total control diseases in III was 666, and for II, was 529.

Annual Cycles of Various Disease Groupings--

As shown in Table 2, Section 4, a number of different lists of control diseases and enteric diseases were selected in the preliminary stages of the study design in order to test the appropriateness of the different groupings as indicators of the effect of varying wastewater utilization practices.

In most of the data analyses in this report, the total enteric and total control classifications were used. For comparative purposes, Figure 25 presents the annual disease cycle for a number of the disease groupings for kibbutzim of categories I and II irrigating between April-October, as shown in Figures 22b and 23b. For purposes of ease of visual comparison, 25a repeats 22b and 25b repeats 23b. From 25c, it was observed that the pattern of a relative summer excess of selected enteric diseases in I over II is similar to that found for total enteric diseases in 25a. Similarly, the seasonal pattern for selected control diseases 1, as shown in 25d resembles that of total control diseases shown in 25b. Influenza, shown in 25e has an even more marked seasonal pattern, but had essentially the same winter peak and summer low as total control and selected control 1. However, in Figure 25f, selected control diseases 2, which includes mainly diseases without a clear seasonal pattern, showed no picture of a consistent annual cycle. A similar pattern was found for the control diseases in all ages in the same grouping of kibbutzim as in Figure 25 when categories I and III were combined and compared to II. This is presented in Figure 26. No observed differences were seen in the 0-4 age group for the same comparisons given in Figure 26.

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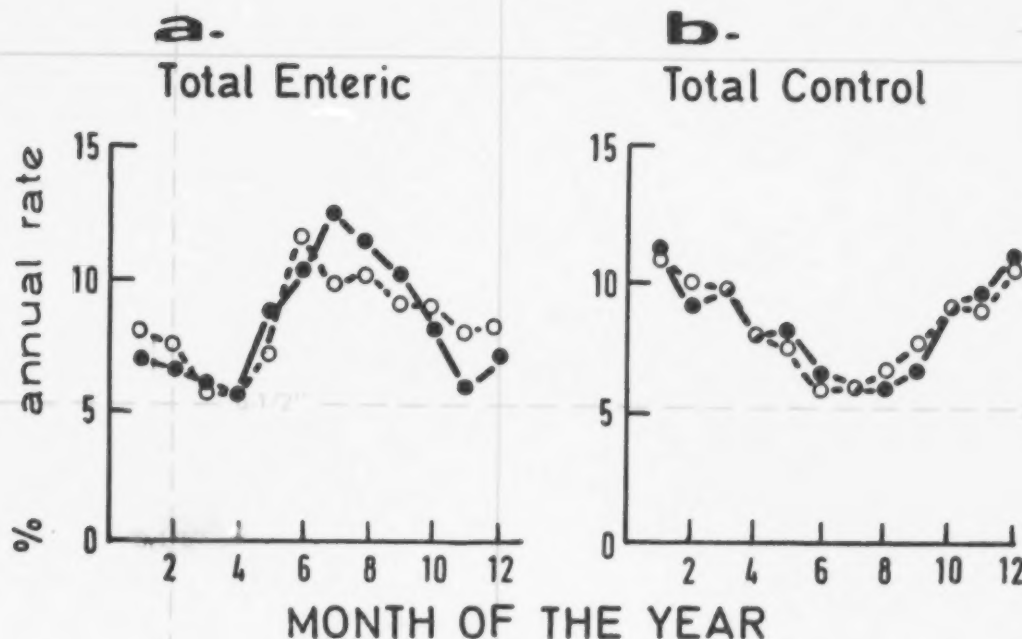


Figure 24. Annual cycles for total enteric and total control diseases in kibbutzim regardless of irrigating periods with non-effluent (II) and effluent feed water in fish pond (III) - all ages.

Cumulative Monthly Disease Rates—

Figure 27 presents the cumulative monthly disease rates over the annual cycle for kibbutzim irrigating April-October only in two different forms. The left hand figures (27, 1 and 3) present the cumulative percent of the annual rate while the right hand figures (27, 2 and 4) present the actual cumulative rate/1000 persons/year. Figure 27a, 1 and 2, for total enteric are based on the same data presented in Figure 25a and clearly illustrate the observation of a more rapid rate (slope) of infection with total enteric disease in I over II during the months of May through July or directly after the initiation of wastewater irrigation in April. The annual levels reached are the same in both I and II (27-2). Figure 27b, 3 and 4 presents a similar finding for selected enteric disease, but here the annual rate of selected enteric disease is higher in I than II (27-4). This figure was based on the data presented in 25c, which also illustrates the excess in I over II after initiation of irrigation.

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○—○ Non Effluent (II)

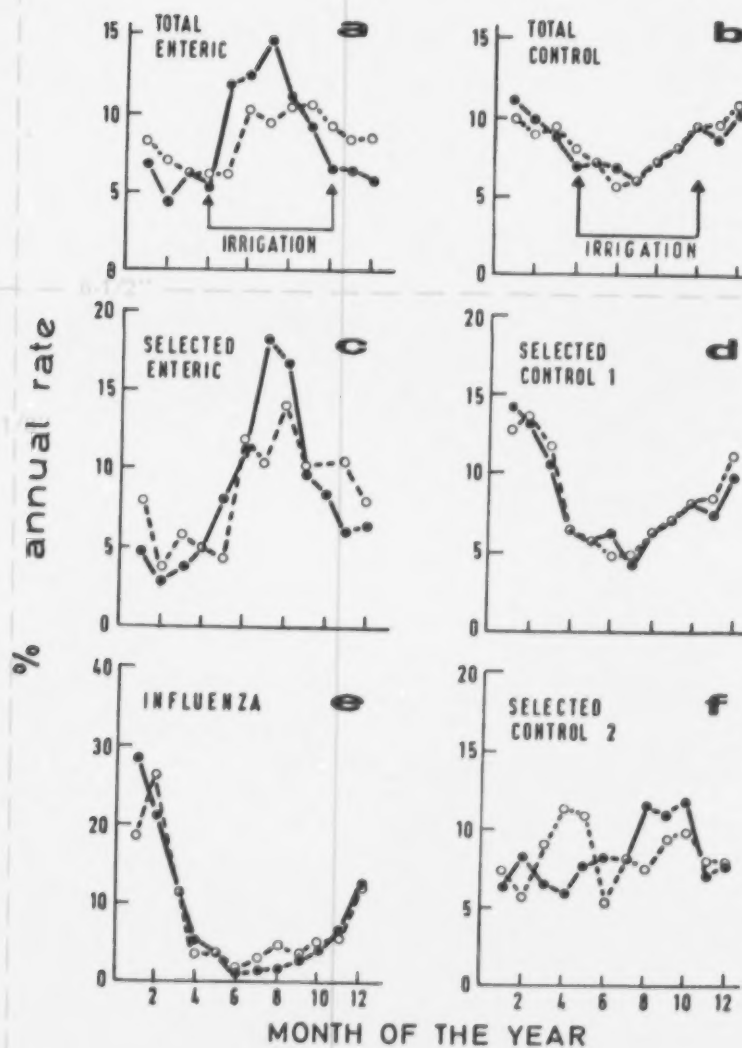


Figure 25. Annual cycle of disease groupings for kibbutzim in categories I and II irrigating between April-October - all ages.

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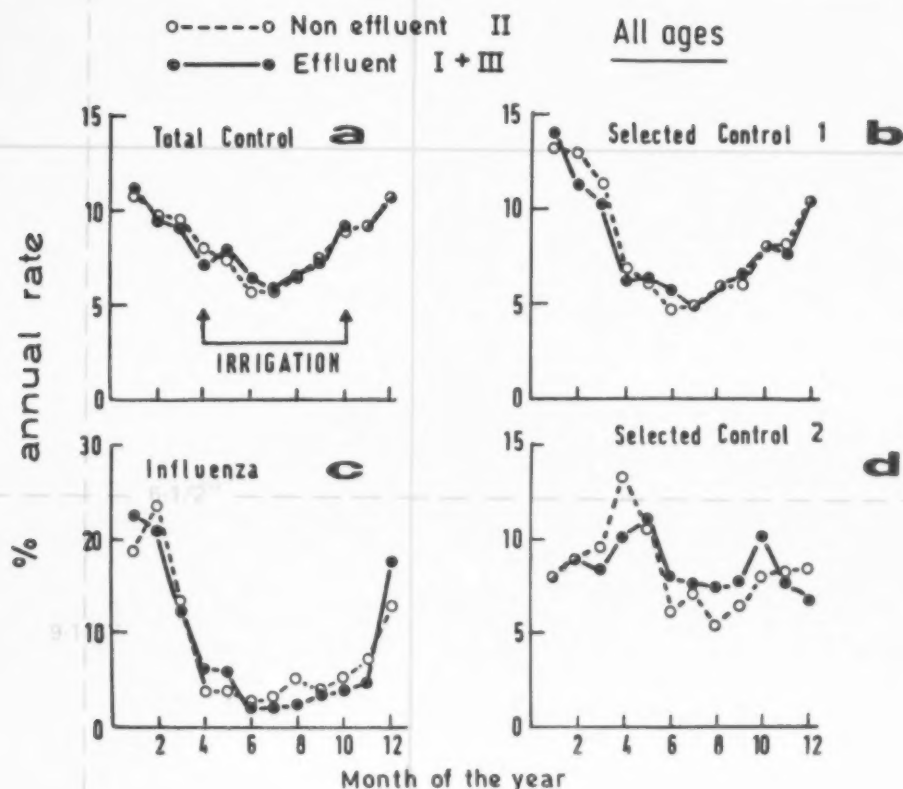


Figure 26. Annual cycle of disease groupings for kibbutzim irrigating between April-October for categories II and I + III combined - all ages.

Figures 28a, 1 and 2 show that while on a percentage basis the cumulative curves for total enteric disease for I and II are essentially the same for those kibbutzim irrigating 12 months a year, there is an annual excess in II over I when actual disease rates are presented. These are based on the same data as presented in 22c. Figures 28b, 3 and 4 indicate that for category III vs. I (I as in 28, 1 and 2), the cumulative curves are also essentially the same on a percentage basis, but there is a clear excess in III over I when absolute disease rates are considered.

From Figures 22b and 27a, 1 and 2, it appears that on an annual basis there is no excess of enteric disease in wastewater irrigating kibbutzim (I) vs. those not utilizing wastewater (II).

Thus, from observing the crude rate, it appears that the population in effluent irrigating kibbutzim have no overall added risk of becoming ill with total enteric disease in any given year than those residing in non-

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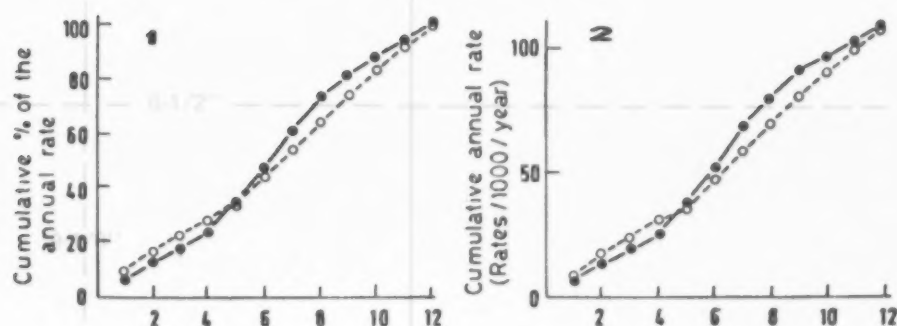
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●—● Category I Irrigation april-october only
○---○ Category II " " " "

a) Total Enteric



b) Selected Enteric

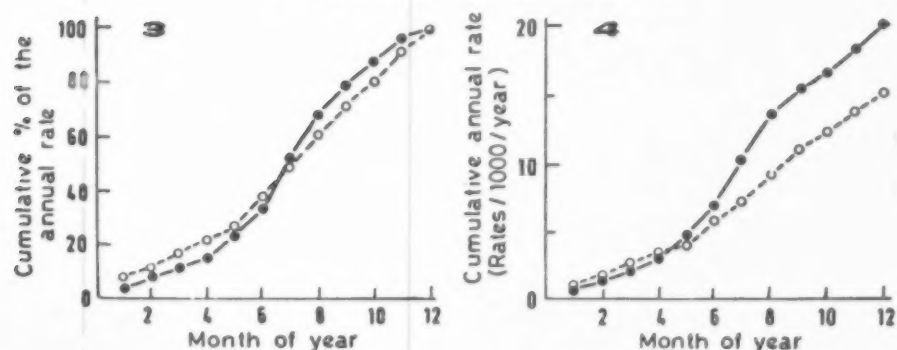


Figure 27. Cumulative disease rate over the annual cycle of total enteric and selected enteric diseases in kibbutzim irrigating during April through October.

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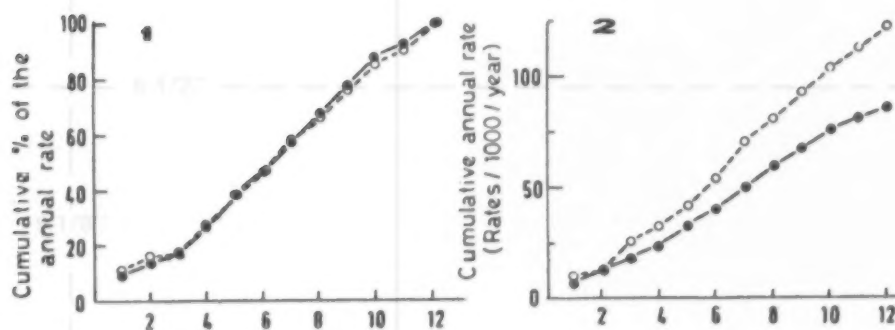
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- Category I - Irrigation for 12 months a year only
- - - - - Category II - " " " " " " " "
- △- - - - - Category III - All kibbutzim regardless of irrigation period

a) I vs. II



b) I vs. III

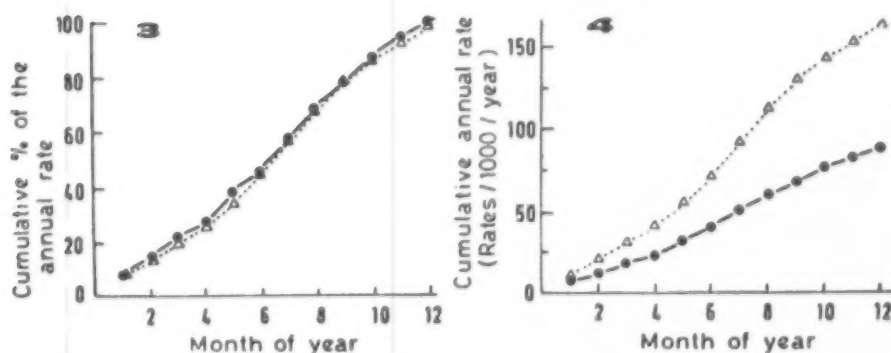


Figure 28. Cumulative annual cycle of total enteric disease during different periods of irrigation by category.

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effluent utilizing communities. These figures suggest that while there indeed appears to be an apparent increase in enteric disease as a result of exposure to wastewater irrigation starting in the spring, there are numerous and multiple other opportunities to become infected and ill with enteric diseases in the kibbutz environment regardless of the wastewater utilization practices. Thus, kibbutz members and residents in non-effluent irrigating kibbutzim appear to reach the same annual level of total enteric disease eventually as those exposed to wastewater irrigation.

It was seen in Figure 22b that in wastewater irrigating kibbutzim I the rate of enteric disease rises rapidly in May-July and reaches higher levels than in category II. However, the rates of enteric diseases in I then drop below II for the rest of the year with the mean annual rates finally equalizing at the same level in both categories.

From these observations of the annual enteric disease cycle, it is suggested that the pool of susceptibles to the broad spectrum of total enteric diseases included in this study do become infected by exposure to wastewater irrigation starting about May each year, but rapidly reach a saturation level by the end of July leading to a lower rate of disease for the remaining months of the year.

A similar phenomenon was reported by Bernstein (1957) for respiratory diseases among U.S. Air Force recruits placed in various barrack arrangements for high and low living quarter densities. The initial rate of infection in the high density barracks were greater than the low density, but by the end of the basic training period both groups had about the same total rate of infection.

The fact that this disease cycle is repeated annually could be explained by the hypothesis that the predominant enteric diseases influencing the annual cycle are diseases such as salmonellosis which provide little or no acquired immunity, thus enabling the pool of susceptibles to be renewed annually and/or that each year a significant number of new susceptibles are added to the pool such as young infants and newly arrived residents. An additional explanation might be that different agents responsible for the same symptoms can circulate in different years. The finding that all age groups are involved in this phenomenon indicates that it is not only the addition of infants that is critical.

The unique nature of collective living, including communal dining rooms and communal living and sleeping of infants and children in common homes, within the context of kibbutzim in Israel apparently provides ample opportunities to become infected with enteric diseases from multiple sources during the course of the year with a certain upper limit or saturation which is not affected appreciably by wastewater irrigation practices.

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Whether or not this same situation would hold for susceptibles residing in private homes as might be found in a typical American community but with equal levels of exposure to effluent irrigation or land disposal systems is not clear. It would not be unreasonable to assume that persons not involved in the same intensive communal contacts and interactions that are unique to

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the kibbutz situation might be faced with an over all added risk as a result of the same degree of exposure to wastewater irrigation.

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For the same kibbutzim irrigating April through October, as shown in 27a, 1 and 2, it should be noted that for selected enteric diseases (27b, 3 and 4) the increased rate of infections in I over II during the months May through July is even more pronounced with an absolute excess in I over II on an annual basis. This finding suggests that there exists a more rapid rate of infection after the initiation of wastewater irrigation ending up with a total excess in I over II on an annual basis. Due to the relatively lower number of cases of selected enteric disease as compared to total enteric disease, this very suggestive finding in the crude rates could not be tested in the logistic and log linear models.

Kibbutzim Irrigating April-October vs. Other Months

In Figure 15a, it was seen that I had an observed lower rate of enteric disease during the irrigation period over II. A possible spurious effect results from the comparison of disease rates during irrigation periods which varied between kibbutzim. It was shown earlier that the mean number of months of irrigation in I was 8.1 vs. 7.2 in II and III, or about 11 percent longer in I. Due to the natural annual cycle of enteric diseases as shown in Figure 21, it can be seen that the longer the irrigation period, the lower the expected enteric disease rate, regardless of actual exposure to wastewater utilization. This was essentially due to the fact that all kibbutzim irrigate in June-August, which are the peak months of the enteric disease cycle. Thus, the longer the irrigation period, the more of the low portion of the cycle was included in the calculated mean enteric disease rate.

In order to examine this question, total enteric disease rates were calculated for those kibbutzim which irrigate wholly or partially in April through October, as compared to the remaining kibbutzim which irrigate for longer periods, including the 16 kibbutzim that irrigate for the full 12 months of the year.

Figures 29a and b show that for those 33 kibbutzim which irrigated in April through October there was a small observed excess in I over II in total enteric disease in all ages, both when the rate was calculated for the total 7-month period (Figure 29a), regardless of actual irrigation period, and when the rate was based on that of the actual months of irrigation exclusively. The mean number of the actual irrigation months (Figure 29b) in I was 6.0 with 4.1 in II and 5.5 in III. Here the excess months of irrigation was 32 percent greater in I than in II. It appears from this finding that the hypothesis concerning the spurious effect of the length of irrigation period is not supported. In Figure 29c and d, the enteric disease rates for the remaining 35 kibbutzim are shown. It should be noted that this group includes those irrigating for 12 months a year, or for any period starting before April or ending after October.

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In Figure 29c, the enteric disease rates during the months of April through October were observably lower in I than in II, with the same pat-

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Category I  Category II = 100%  Category III 

ONLY APRIL-OCTOBER
IRRIGATING KIBBUTZIM

ALL THE OTHER
KIBBUTZIM

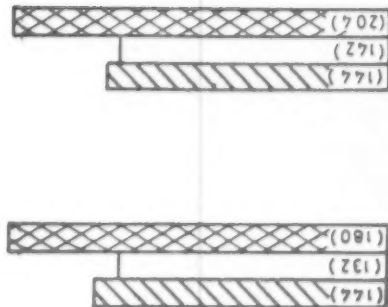
200
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0
% episode rates

All
7 months

Irrigation
months

April-October

All
Irrigation months



b

c

d

Figure 29. Comparison of total enteric disease rates in kibbutzim irrigating in April through October vs. the others, by category - all ages (Figures in columns are rates of episodes/1000 persons/year.)

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tern for the total irrigation period shown in Figure 29d. In this, the mean number of months of irrigation in I was 9.9 with 10.2 in II and 9.8 for III, or almost equal to each other.

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This suggests that while there may be an effect associated with the length of the irrigation period, as suggested above, other factors appeared to influence the lowered enteric disease rates in kibbutzim practicing effluent irrigation 12 months a year or during longer periods than in the group irrigating between April through October. Whether or not this could be associated with some form of immunity resulting from exposure to effluent over long periods could have been determined only by serological tests which were not included in this study.

Another possible explanation is the effect of the specific geographical region, since the kibbutzim with longer irrigation periods were clustered in the southern region of the country. Figure 19 showed that in general the rates for total enteric disease in the southern region were lower than in all other regions. Why this should lead to lowered enteric disease rates in effluent irrigating kibbutzim is not clear.

Comparison of Annual Disease Rates - Irrigation and Non Irrigation Periods Combined

Total Enteric and Total Control--

Up to this point we have compared disease rates during irrigation and non irrigation periods, or during defined summer or winter seasons, or on a monthly basis. In the final analysis the public health impact of land application of wastewater must be measured by the differences in the annual disease rates between communities with different wastewater utilization practices.

Figure 30 presents a comparison of the annual rates (irrigation and non-irrigation periods combined) for total enteric and total control diseases in categories I, II and III, as well as for all categories combined for all ages. As before, the rates in category II are presented as 100 percent.

The observed lower rate of enteric disease in I vs. II found during the irrigation period, as shown in Figure 15a, remains as does the excess in III over II. Control diseases in I and II were essentially equal, with III showing an observed excess over II.

The rates for all categories combined were about equal to those of category II.

Specific Enteric and Control Diseases--

Table 10 presents the annual rates of clinic visits and episodes for all of the 24 specific disease entities included in the study by kibbutz category and for all categories combined for all ages.

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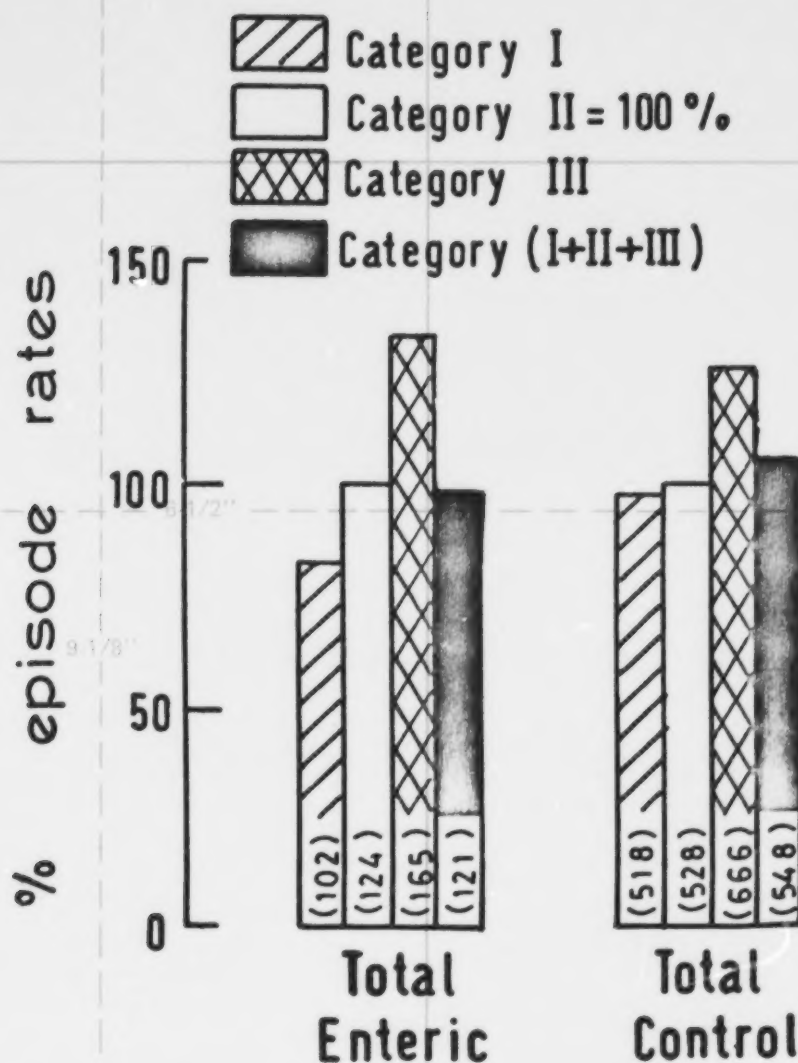


Figure 30. Comparison of the annual total enteric and annual total control disease rates by category for all ages - irrigation and non-irrigation periods combined (Figures in columns are rates of episodes/1000 persons/year).

Figure 31 presents, in graphic form, the comparison of the rates of six prevalent enteric diseases and six prevalent control diseases by kibbutz category.

Bacillary dysentery (shigellosis) is the only specific enteric disease that appeared in excess in category I over II on an annual basis (Figure 31)

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TABLE 10. THE ANNUAL RATE OF CLINIC VISITS AND EPISODES
FOR ALL SPECIFIC DISEASES BY KIBBUTZ CATEGORY

Diseases	Rates/1000 persons/year (irrigation and non-irrigation periods combined)					
	Category I	Category II	Category III	All Categories	Category I	Category II
	Visits	Episodes	Visits	Episodes	Visits	Episodes
Typhoid Fever	1	1	1	0	0	1
Paratyphoid	-	-	0	-	21	0
Salmonella Infections	7	6	12	17	31	19
Bacillary Dysentery	29	28	25	29	387	28
Gastro-Enteritis	270	252	357	350	1	322
Aseptic Meningitis	1	1	1	1	1	1
Infectious Hepatitis	7	6	9	7	8	7
Upper Respiratory	757	672	804	754	856	792
Influenza	67	65	129	148	150	104
Urinary Tract Infections	133	117	170	128	150	102
Food Poisoning	1	1	1	0	195	114
Fever of Unknown Origin	73	70	127	181	3	108
Coxsackie Virus Infections	2	2	13	3	1397	4
Throat Infections	938	855	1029	1246	1049	942
Measles	5	5	13	2	2	5
Chickenpox	46	22	72	75	61	60
Accidents	90	89	120	131	128	107
Rubella	4	4	10	9	1	6
Mumps	47	46	67	65	24	50
Pneumonia	30	29	28	25	35	30
Bronchitis	163	155	220	147	168	172
Parasitic Infections	34	33	40	42	43	38
Amebiasis	9	9	16	3	3	11
Leptospirosis	1	1	-	1	1	0
Total	2,716	2,492	3,252	3,321	3,685	3,080
Total Population	13,531	11,096	5,005	29,632		

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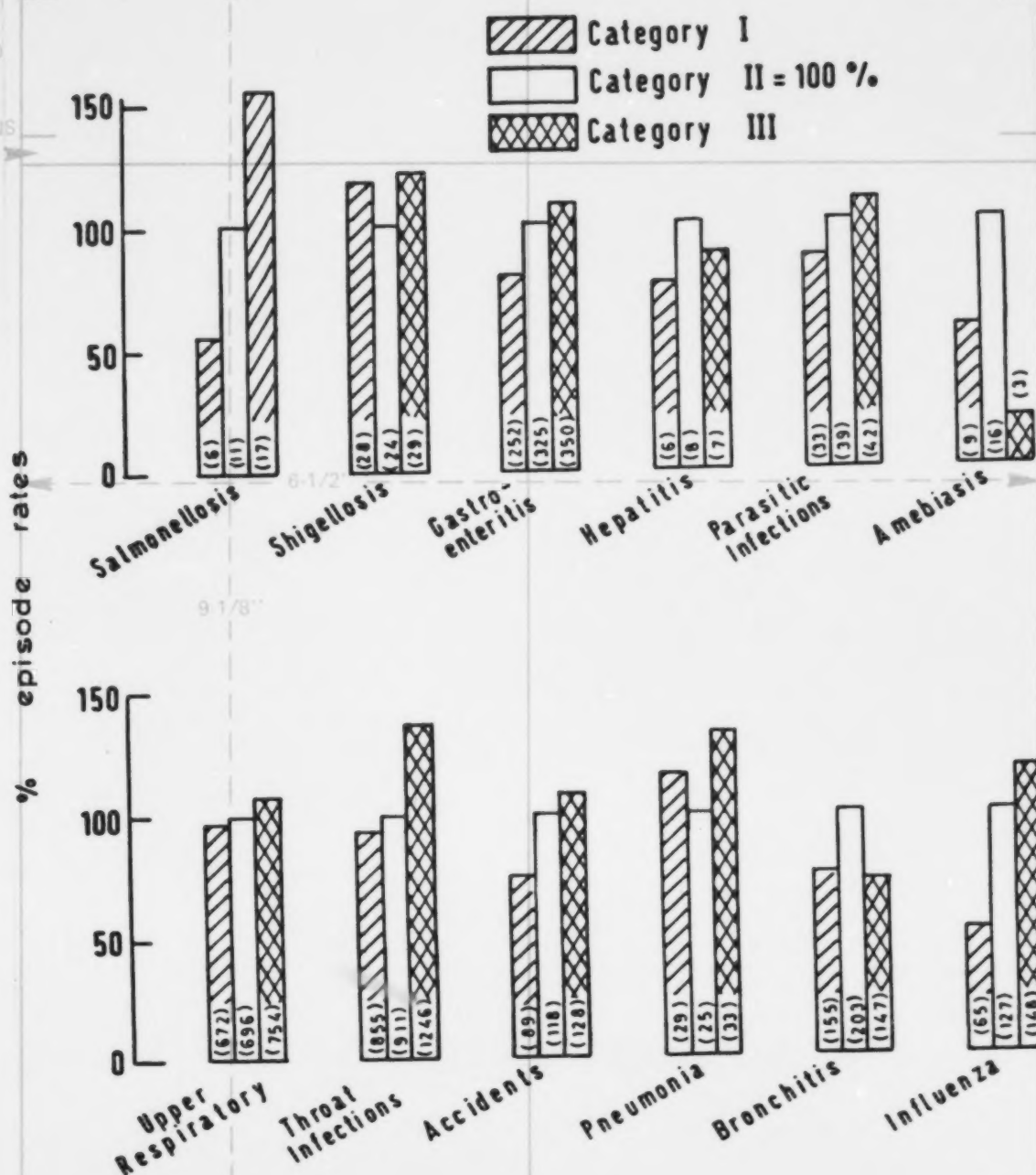


Figure 31. Comparison of annual rate of episodes of 12 prevalent specific enteric and control diseases for all ages by kibbutz category - irrigation and non-irrigation periods combined. (Figures in columns are rates of episodes/1000 persons/year.)

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as well as during the irrigation period as shown in Figure 17a. The other enteric diseases had lower rates in I than in II. The mean annual rates found in this study over the four year period for a few selected infectious diseases were compared to those reported for the total Jewish population in Israel (Central Bureau of Statistics, 1981). The published rates for 1975 were based exclusively on physician's notifications of cases of infectious diseases, which must be reported to the Ministry of Health according to the law. The rate of typhoid fever found in this study, in all categories, was 100/100,000 persons as compared to 2/100,000 reported to the Ministry of Health. Bacillary dysentery was 2700/100,000 in this study, as compared to 148/100,000. Infectious hepatitis was 700/100,000 in this study compared to 79/100,000. However, reported rates for kibbutzim are higher than the total population (Ministry of Health Monthly Epidemiological Bull., Vol. 16, Aug. 1981). For shigellosis, the rates for 1974-77 ranged from 684-1030/100,000 (mean 861), with rates for towns ranging from 104-145 (mean 121).

The rates for the above diseases range from 7-50 times higher than rates for urban or total, based on this study and Ministry of Health data.. This does not necessarily mean that the kibbutz population suffers from more infectious diseases than the population at large, but did indicate the higher level of reporting within the kibbutz context in general, although it was recognized that there was considerable inter-kibbutz variation.

A further analysis of the findings of this study, compared to infectious disease notification to the Ministry of Health, is presented later.

Analysis of Data within Category I

The Effect of Utilizing Local and Non-Local Wastewater Effluent--

Within category I (effluent irrigating), 18 kibbutzim with a population of 8166 used only effluent derived from the kibbutz itself, while another group of 12 with a population of 5365 used effluent brought in from a neighboring community and their own effluent. It had been hypothesized that the exposure to pathogens in wastewater effluent derived from a neighboring community would present a potentially higher risk of infection from enteric disease due to the lower state of immunity that would exist in the community, as compared to those communities exposed to their own wastewater only. That is, a higher level of immunity should exist within a kibbutz to the pathogens which appear in its own effluent, since those diseases are endemic within the community and immunity is acquired through a continual recycling or reinoculation process and through continual contact.

Figure 32 compares the rates of episodes of total enteric and control diseases in kibbutzim using only local effluent (calculated as 100 percent), to those using a combination of other effluent and local effluent. There was no excess of total enteric enteric diseases in kibbutzim using effluent from non-local sources to those from local sources in the irrigation period. There was, however, an observed excess in total control diseases in this period. During the non-irrigation period, there was an apparent small difference of total enteric and total control diseases between the two groups.

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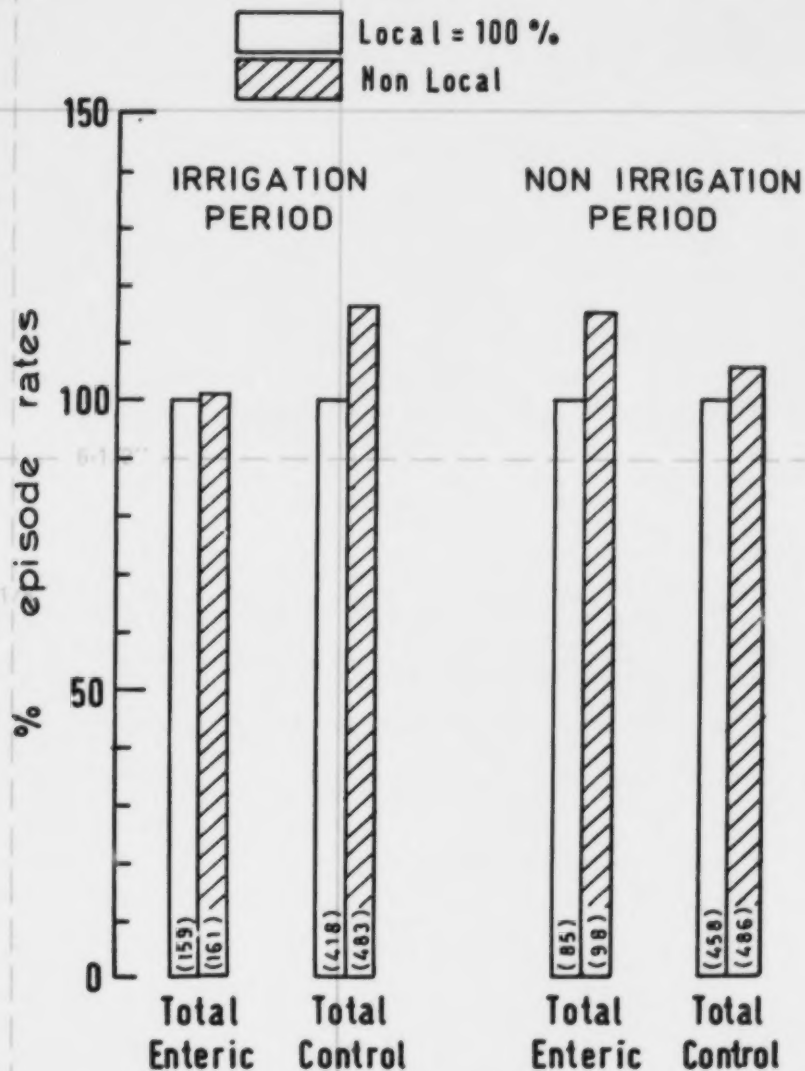


Figure 32. Comparison of episode rate of local vs. non-local effluent in disease groups during irrigation and non-irrigation periods for all ages. (Figures in columns are rates of episodes/1000 perons/year.)

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Effect of Exposure to Wastewater Aerosols on Disease Rates--

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In this study, no field measurements were made of the concentrations of aerosolized bacteria or viruses from wastewater sprinkler irrigation. In the absence of such data, an analysis of a number of proxy factors has been made in the 30 kibbutzim of category I to approximate the effect of exposure to wastewater aerosols on disease rates.

Exposure index for aerosolized wastewater--In order to estimate the degree of exposure of the residential area in the effluent irrigated kibbutzim to airborne microbial aerosols, an exposure index equation has been established. This equation is based on some of the major parameters assumed to be involved in the aerosol production and transport. Each parameter was placed in the exposure index equation according to its assumed negative or positive effect on the exposure.

$$E = \frac{A \cdot F \cdot T}{V \cdot D^2}$$

Where:

- E Exposure
A Area: size of irrigated fields in 1000·m²
F Frequency of wind direction (all velocities) in percent
T Time period of irrigation of field (in months)
V Velocity, mean wind, in m/sec.
D Distance from the nearest edge of the field to the central dining room (in meters)

Method of calculation--

- E (Exposure Index) was calculated separately for each effluent irrigated field according to its A (area).
- F (Frequency of wind direction) was calculated as follows: the frequency of the predominant wind sector (22.5°) from the irrigated field towards the kibbutz dining room plus 50 percent each of wind frequencies of the two adjacent wind sectors (22.5°). When the field was located on two or more sectors on the "wind-rose", frequencies of all the wind velocities in these sectors, plus 50 percent of the two adjacent sectors, were taken.
- T (Time period of the irrigation of the field in months) was calculated individually for each field according to the number of months that the field was under irrigation.
- V (Velocity, mean wind) was calculated for each month as follows:

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$\frac{(V \cdot F)}{F}$: the sum of 100 percent of the multiplication of F by

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the V of the main wind direction, plus 50 percent of the two adjacent wind directions, divided by the sum of the "F" 's...for example: At Kibbutz X in April, conditions were:

WIND DIRECTION				
ENE	E	ESE	SE	
F	F1	F2	F3	F4
V	V1	V2	V3	V4

The cotton field was East and East-South-East of the central dining room, and the calculation was made as follows:

$$\frac{1/2 (F1 \cdot V1) + (F2 \cdot V2) + (F3 \cdot V3) + 1/2 (F4 \cdot V4)}{1/2 F1 + F2 + F3 + 1/2 F4} = V, \text{ for April.}$$

The sum of the results for the entire irrigation season was divided by the number of months and the result was used as the mean velocity -- V -- in the exposure equation.

- D (Distance from the nearest edge of the irrigated field to the central dining room) was squared because of its strong influence on the airborne microbial concentration of the aerosols, which are affected by both physical dispersion and biological die-away.

The sum of the "E" of the various irrigated fields at a given kibbutz served as the index of exposure.

Meteorological data were obtained from a newly published report of the Meteorological Service, Ministry of Transportation, Beit Dagan, (Manes et al., 1980), which included information from the 140 meteorological stations throughout the country. The meteorological data for the study period for any given kibbutz was taken from the nearest meteorological station (see Figure 2).

Correlation between exposure index and disease rate--Table 11 presents the index of exposure for each kibbutz in category I in increasing order. In adjacent columns, are the annual visit rates/person/year for all ages of total enteric and total control diseases.

The coefficient of correlations was calculated for the actual index whose size varied by a factor of about 10,000 from the smallest to the largest. A second calculation was based on the log of the index of exposure, thus decreasing the range of smallest to largest to a factor of 4.

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For the exposure index itself, the r for total enteric disease was 0.053 and for total control disease was 0.101. When the log of the index was used

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TABLE 11. EXPOSURE INDEX AND RATES/PERSON/YEAR FOR TOTAL
ENTERIC AND TOTAL CONTROL DISEASES FOR ALL
AGES FOR EFFLUENT IRRIGATION KIBBUTZIM (I).

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Kibbutz Code	Exposure Index	Enteric Disease	Control Disease
A37	0.000033	0.04	0.51
A51	0.00015	0.11	0.43
A41	0.00120	0.15	0.76
A32	0.00132	0.03	0.07
A47	0.00145	0.11	0.72
A49	0.0021	0.10	0.87
A38	0.0033	0.07	0.33
A44	0.0034	0.15	0.64
A22	0.0039	0.00	0.11
A27	0.0061	0.18	0.63
A42	0.0064	0.08	0.42
A25	0.0067	0.04	0.42
A50	0.0070	0.05	0.21
A28	0.0075	0.03	0.16
A35	0.0088	0.15	0.88
A39	0.0115	0.29	1.03
A23	0.0139	0.10	0.80
A21	0.0160	0.04	0.25
A31	0.0168	0.02	0.17
A36	0.0219	0.19	0.75
A29	0.0219	0.09	0.53
A40	0.0346	0.14	0.44
A24	0.0395	0.06	0.25
A34	0.0706	0.09	0.73
A45	0.0914	0.09	0.56
A43	0.1019	0.08	0.38
A48	0.1115	0.16	0.76
A33	0.1311	0.14	0.65
A46	0.2183	0.09	0.54
A26	0.2398	0.10	0.37

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the r for total enteric disease was 0.127 and for total control disease was 0.139. From these results, there is no indication of an association between the calculated index of exposure or its log and enteric or control disease.

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In addition to the preceeding calculation, we calculated the correlation between the index of exposure and the rates of enteric and control diseases only for the period between April and October (the main period of exposure to effluent irrigation) for the following divisions of category I kibbutzim:

- 1) All kibbutzim: total 30.
- 2) Those kibbutzim which irrigated with effluent from April to October (or for part of that period): total 14.
- 3) Kibbutzim which irrigate for 12 months per year: total 7.

The coefficient of correlation for the exposure index and the log of the exposure index for enteric and control diseases for each of the three above groups of category I kibbutzim, are summarized in Table 12.

In a further effort to examine the question of the effect of the degree of exposure to wastewater aerosols on disease rate, some of the parameters were examined separately.

Effect of distance from effluent irrigated field--For category I kibbutzim (effluent irrigation), the effect of the distance from the closest effluent irrigated fields on enteric disease rates was analyzed. The 30 kibbutzim in category I were divided into four groups on the basis of the distance between the closest irrigated field and the kibbutz dining room

TABLE 12. CORRELATION BETWEEN EXPOSURE INDEX AND LOG OF EXPOSURE INDEX AND RATES/1000 PERSONS/7 MONTHS FOR ENTERIC AND CONTROL DISEASES DURING THE PERIOD APRIL THROUGH OCTOBER ONLY.

Group of Kibbutzim	Coefficient of Correlation of Exposure Index		Coefficient of Correlation of Log Exposure Index	
	Enteric Rates	Control Rates	Enteric Rates	Control Rates
All	0.053	0.101	0.127	0.139
April-October	0.080	0.265	0.013	0.208
12 Months	0.301	-0.009	0.390	-0.100

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1. 300 meters or less
2. 301-450 meters
3. 451-600 meters
4. 601 meters and above

In Figure 33, the disease rate for the first group of kibbutzim (300 m or less) was calculated at 100 percent, with the rates of the other groups compared to it. The disease rate for all ages during the irrigation period in kibbutzim where the dining room was more than 300 meters distant was higher for the total enteric disease group as well as for the total control group.

The same finding was shown in the 0-4 age group alone. This result provides no support for the assumption that enteric disease rates are inversely associated with the distance from aerosolized wastewater sources.

Effect of size of effluent irrigated fields--Figure 34 presents the findings associated with the relationship between the enteric disease rates in category I kibbutzim and the size of the irrigated plot. Kibbutzim were grouped as follows:

1. ≤ 5 hectares
2. 5.1-10 hectares
3. 10.1-50 hectares
4. < 50 hectares and above

No differences were seen in disease rates during the irrigation period between the various plot sizes in the "all ages" group. There was evidence that the 0-4 age group showed increased rates of total enteric disease in the three larger plot size groups above 5 hectares.

Effect of volume of wastewater irrigated--Figure 35 presents the findings associated with the relationship between the enteric and control disease rates in category I kibbutzim during the irrigation period and the volume of wastewater irrigated per year.

The kibbutzim were grouped as follows:

1. ≤ 55 thousand m^3 /year
2. 56-169 thousand m^3 /year
3. 170+ thousand m^3 /year

In the 0-4 age group and all ages, there were lower total enteric and total control disease rates in the kibbutzim utilizing wastewater effluent volume of 56,000 m^3 /year and greater. This result provides no support for the assumption that enteric disease rates are positively associated with the volume of wastewater used for irrigation.

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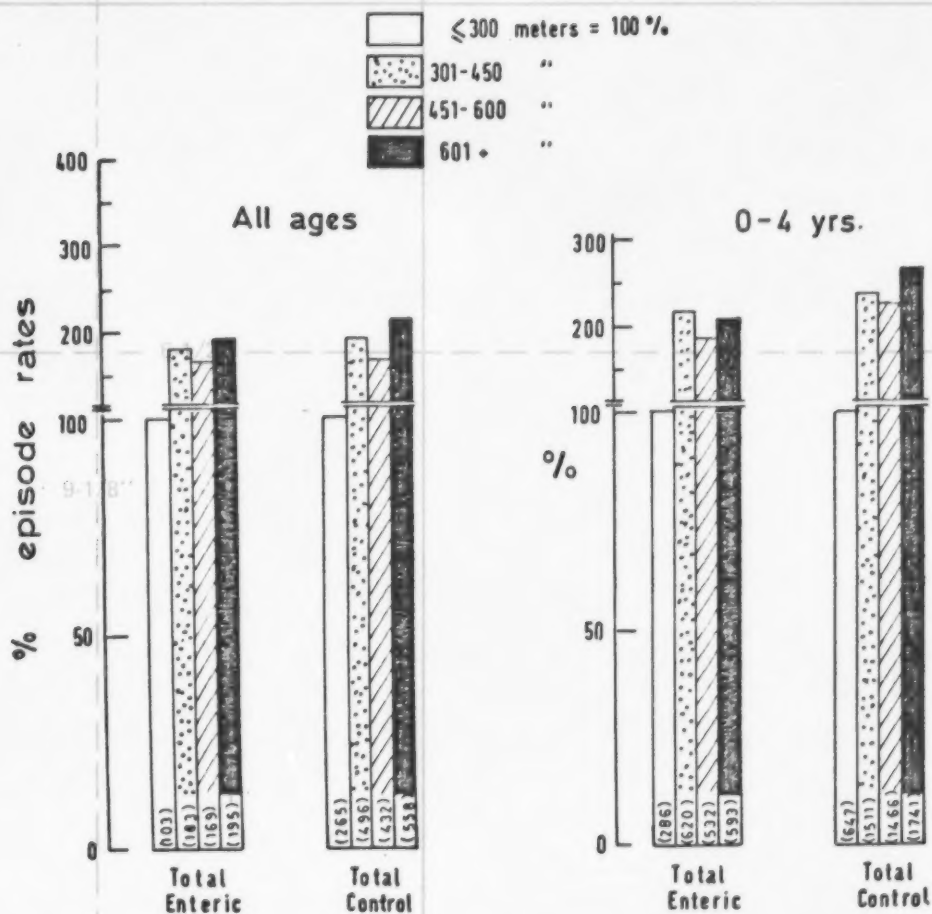


Figure 33. Effect of distance of effluent irrigated tracts from dining room on the rates of total enteric and total control diseases during irrigation period for 0-4 years and for all ages. (Figures in columns are rates of episodes/1000 persons/year.)

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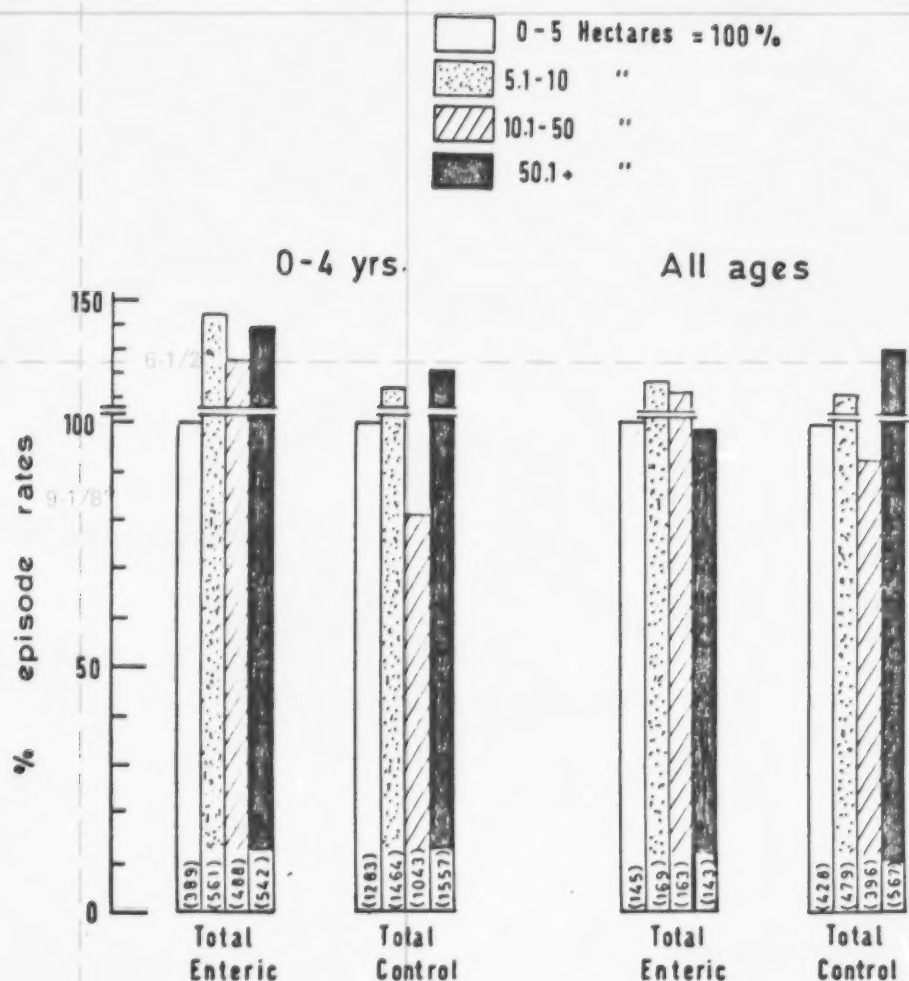


Figure 34. Effect of size of effluent irrigated tracts on the rates of total enteric and total control diseases during irrigation period for 0-4 years and for all ages. (Figures in columns are rates of episodes/1000 persons/year.)

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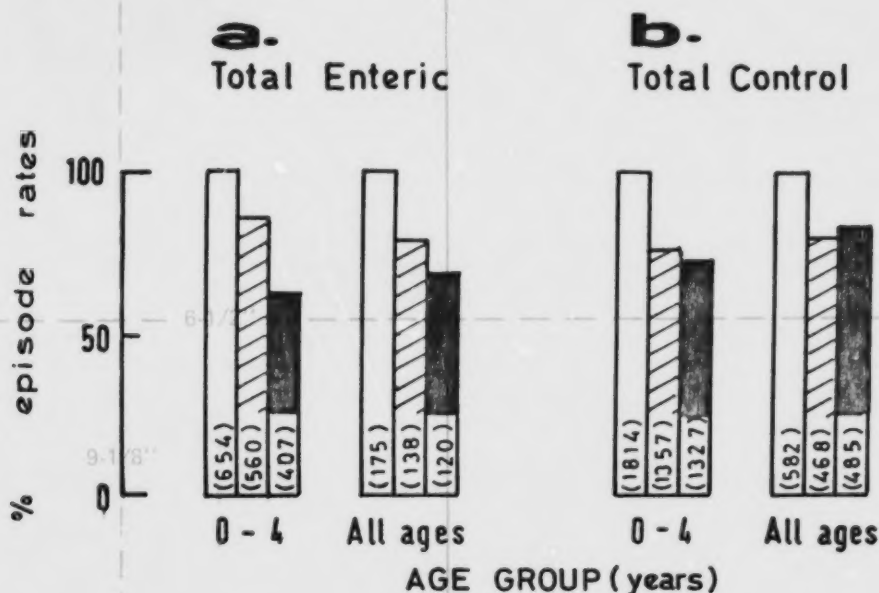
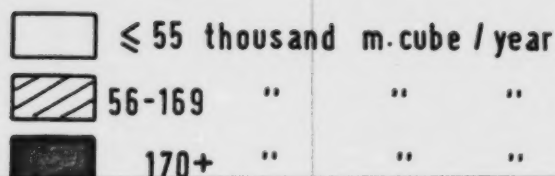


Figure 35. Effect of mean volume per year of wastewater used for irrigation on the rates of total enteric and total control diseases during irrigation periods for 0-4 years and all ages. (Figures in columns are rates of episodes/1000 persons/year.)

The Problems Arising from Lack of Control Group for III

As mentioned, kibbutzim using effluent as feed water for fish ponds (III) did not have an appropriate control group of similar kibbutzim with fish ponds not utilizing effluent, consequently no comparison of disease rates could be made. Fish ponds not utilizing effluent do, however, use cow manure, chicken manure and drainage from barns. This practice undoubtedly introduced salmonellae organisms in high concentrations into the ponds since recent studies indicate that salmonella isolates were obtained from non-effluent enriched fish ponds (Guttman-Bass, et al., 1981).

A small comparative study of three kibbutzim based on morbidity data from the Ministry of Health records may provide some insight on this problem at least from a qualitative point of view (Noe-Mocetti, 1981). The study included one kibbutz from category III, one from category II and an additional

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kibbutz with fish ponds not utilizing effluent as a more appropriate control for III. Although no statistical analysis was possible it was interesting to note that over a six year period enteric disease rates for all ages in the category III kibbutz was about equal to that of the non-effluent fish pond kibbutz while both rates were some 40 percent greater than the non-effluent utilizing kibbutz.

In tests of fish pond water salmonella bacteria were isolated from both the effluent and non-effluent fish ponds. Enteric viruses, however, were isolated only in the effluent fed fish pond.

Caution must be exercised in drawing conclusions as to the meaning of the excess enteric disease rates which were observed in category III over II. Whether this excess is associated with effluent utilization or with general practices of fish pond fertilization with cow and chicken manure cannot be determined when gross categories of enteric disease or salmonellosis are considered. Shigellosis rates in III were essentially the same as for I (Figure 17b.)

Comparison of Kibbutz Clinic Files and Ministry of Health Records

In the Katzenelson et al. (1976) retrospective study on this subject, the findings were based only on notifications of communicable diseases to the Ministry of Health as required by law for a number of diseases including salmonellosis, shigellosis and infectious hepatitis, in non-effluent irrigating kibbutzim vs. effluent irrigating kibbutzim.

Since the morbidity data used in the present study was based only on the kibbutz clinic files, we decided to compare these data with the same source as used in the 1976 study, i.e., Ministry of Health reports for the three above-mentioned communicable diseases for the period of 1 January, 1974 to 31 December, 1977. This comparison of the data dealt only with the 68 kibbutzim.

Comparability of Data--

The completeness and reliability of official notifications to the Ministry of Health for specific communicable diseases as required by law is open to question. We compared the number of reported cases to the Ministry of Health of salmonellosis and shigellosis (the two enteric diseases requiring notification and showing the largest number of cases), with the number of visits for these same diseases from the kibbutz clinic files during the four-year study period.

For shigellosis, 32 project kibbutzim made no report to the Ministry of health. However, clinic files indicated that of these 32, 15 kibbutzim did have records of visits (1 or more) for shigellosis in kibbutz clinic files, i.e., only 17 showed zero cases for this disease in both Ministry of Health and kibbutz clinic records. Moreover, 5 kibbutzim showed zero cases in clinic files for shigellosis but did report 1 or more cases to the Ministry of Health. Thus in 20 kibbutzim, clinic files and Ministry of Health records for shigellosis do not match for zero cases.

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For salmonellosis, of 32 project kibbutzim reporting zero cases to the Ministry of Health, 9 kibbutz clinics had records for 1 or more visits for this disease and only 23 showed zero cases for this disease in both Ministry of Health and kibbutz clinic records. Moreover, 12 kibbutzim had no record in clinic files of this disease but did report 1 or more cases to the Ministry of Health, i.e., 21 kibbutzim showed a lack of correspondence between clinic and Ministry of Health records for salmonellosis.

Table 13 shows the comparison between the number of cases over the same 4 year study period of 8 different diseases as reported to the Ministry of Health and as recorded as episodes in the kibbutz clinic files. These data cover the total study population categories I + II + III combined.

For each disease the number of cases as based on clinic files was approximately equal to or greater than the number reported to the Ministry of Health. For shigellosis, salmonellosis and leptospirosis, the number of cases are about the same; for infectious hepatitis 2 times as many, and for typhoid fever 4 times as many cases are recorded in the kibbutz files as appear in the Ministry of Health reports.

TABLE 13. COMPARISON BETWEEN THE NUMBER OF CASES OF DIFFERENT DISEASES REPORTED TO MINISTRY OF HEALTH AND EPISODES OF KIBBUTZ CLINIC OVER 4 YEAR PERIOD FOR CATEGORIES I - III FOR ALL AGES.

Disease	No. of Cases Ministry of Health	No. of Kibbutz Clinic Episodes
Typhoid Fever	4	19
Paratyphoid	0	4
Salmonellosis	307	293
Shigellosis	803	788
Aseptic Meningitis	29	39
Infectious Hepatitis	93	212
Streptococcal Throat Infection	89	6,431*
Leptospirosis	14	14

*Laboratory confirmed diagnoses only. the overall number of episodes of throat infection was 27,756.

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Apparently very few cases of streptococcal throat infections were reported to the Ministry of Health compared to the actual numbers of cases, as recorded in clinic files. About 23 percent of the clinic recorded episodes are laboratory confirmed, but even then there was considerable underreporting to the Ministry of Health i.e., only about 1 percent were

officially reported. Comparison of the rates for most diseases by kibbutz categories was not considered meaningful due to the small number of cases. However, it was noted that of the 14 cases of leptospirosis reported to the Ministry of Health and also recorded in the kibbutz clinic files, none were in category II with remaining cases divided between categories I and III. Those numbers were too small to enable any quantitative analysis, but are suggestive of an association between effluent utilization and leptospirosis, as has been reported in some countries.

From the above observations, it appears that the two data bases are not entirely comparable and that in some cases reports to the Ministry of Health are made for specific diseases but the cases are not recorded in clinic files, while in other situations cases are recorded in clinic files but not reported to the Ministry of Health.

Comparison of Effluent vs. non-effluent Utilizing Kibbutzim--

Figure 36 compares the rates/1000 persons/year (adjusted to 12 months) for infectious hepatitis, shigellosis and salmonellosis in effluent utilizing kibbutzim (I and III) vs. non-effluent utilizing kibbutzim (II) during the irrigation period for the age group 0-4 and all ages.

Here, both episodes and laboratory confirmed cases from kibbutz clinic files are presented separately and compared with cases reported to the Ministry of Health. The Ministry of Health reports are normally based on laboratory confirmed cases of salmonellosis and shigellosis. For purposes of comparability, we have therefore shown laboratory confirmed cases appearing in the clinic records as well as episodes used as the basis for analysis in most sections of this study.

The total number of cases of infectious hepatitis was too small to allow for a meaningful analysis of the differences of rates between the categories as is shown in Figure 36a. In Figure 36b there was an observed excess in shigellosis in I + III over II according to the Ministry of Health records in both "0-4" and "all ages" with no excess in the 0-4 age group and a slight excess in "all ages" both for episodes and laboratory confirmed cases according to clinic records. Rates of salmonellosis (Figure 36c) were 3.36 times greater in I + III over II according to the Ministry of Health reports in the 0-4 age group, with clinic files not showing any clear excess. For "all ages" there appears to be an excess in I + III only for laboratory confirmed cases based on clinic files.

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Effluent (I+III)
Non Effluent (II) = 100 %.

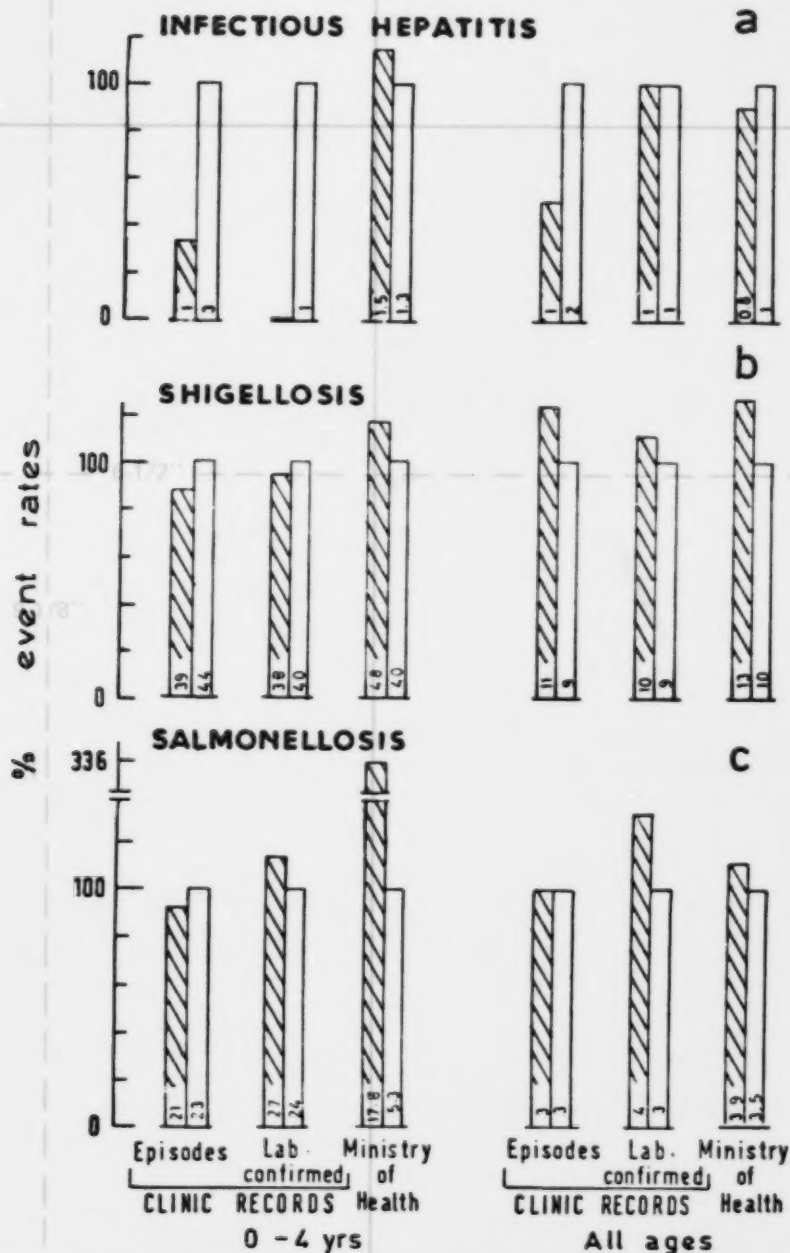


Figure 36. Comparison of event rates/1000 persons/year adjusted to 12 months of kibbutz clinic records and Ministry of Health records during irrigation periods by category I + III vs. II in ages 0-4 and all ages. (Figures in columns are rates of events/1000 persons/year.)

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Comparison of Categories I, II and III Separately--

In order to refine these comparisons we further compared the rates of categories I, II and III separately.

Figure 37 shows that the excess of cases of shigellosis in the Ministry of Health reports were concentrated entirely in kibbutzim utilizing effluent in fishponds (III), in both the "0-4" and all ages group during the irrigation period. No excess in I over II was observed. As for salmonellosis, the rate in the 0-4 age group in III, was 7.2 times greater than II and 2.0 times greater in I than II. In "all ages", the rate of salmonellosis was 1.8 times greater in III than II with no excess in I over II. No excess of infectious hepatitis in I or III over II was observed. For purposes of convenient comparison, the rates for laboratory confirmed cases from the clinic files are also presented.

Figure 38 examines the same diseases for all ages, as Figure 37, but did so for annual rates, i.e., for the irrigation and non-irrigation periods combined.

It can be seen from Figure 38a and 38b that there was no observed excess in the annual rates of infectious hepatitis in the three categories for this period, neither in the Ministry of Health records nor in kibbutz clinic files. There was an observed excess of shigellosis in III over II and of salmonellosis in II over I in both sources of records. It may be noted that the Ministry of Health rates were not always the same as the clinic rates.

Figure 39, summarizes our data (39a) vs. the Katzenelson et al. (1976) data (39b). The rates in the 1976 study were adjusted to 12 months and not presented as seasonal means. In the 1976 study, the medical data were culled from the Ministry of Health records while the present study (39a) shows kibbutz clinic episode data.

In the 1976 study, the summer season was April-November and winter was December-March. In the present study, summer is April-October and Winter November-February. For technical reasons, it was not possible in the presentation to make the length of the summer and winter seasons of the two studies the same.

It can be seen from this figure that the rate/100,000 persons/year for salmonellosis and shigellosis in category I, summer season, was higher in the 1976 study than in our study, while for hepatitis the rates were identical.

In category II, however, the rates for salmonellosis, shigellosis and hepatitis were lower in the 1976 study than in the present study, thus leading to the apparent excess in I over II.

For the winter season, the rate for shigellosis and hepatitis in the 1976 study were much lower than for the present study.

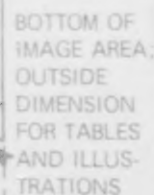
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Ministry of Health

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Kibbutz Clinic

Category I
Category II = 100 %
Category III
Category I+II+III

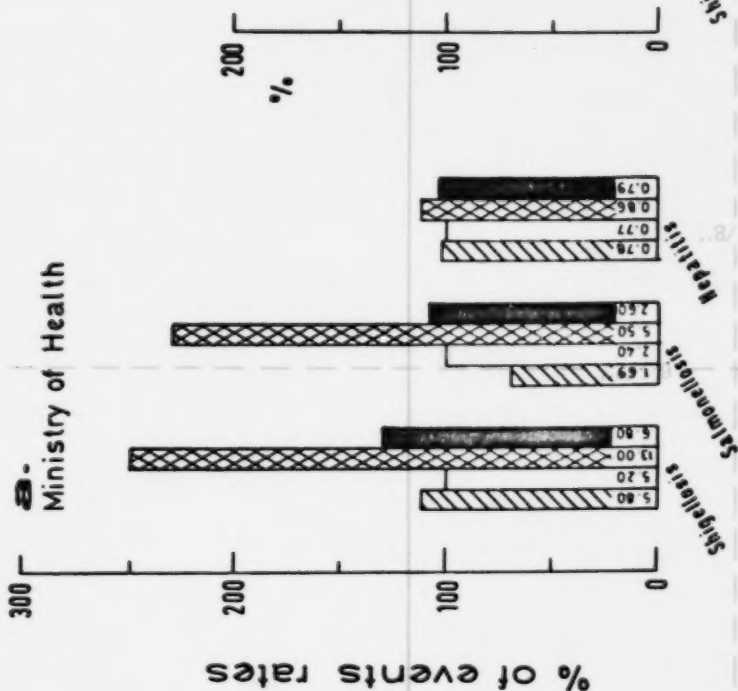


Figure 38. Comparison of annual event rates/1000 persons of kibbutz clinic episodes and Ministry of Health records during the irrigation and non-irrigation periods combined by categories in all ages. (Figures in columns are rates of events/1000 persons/year.)

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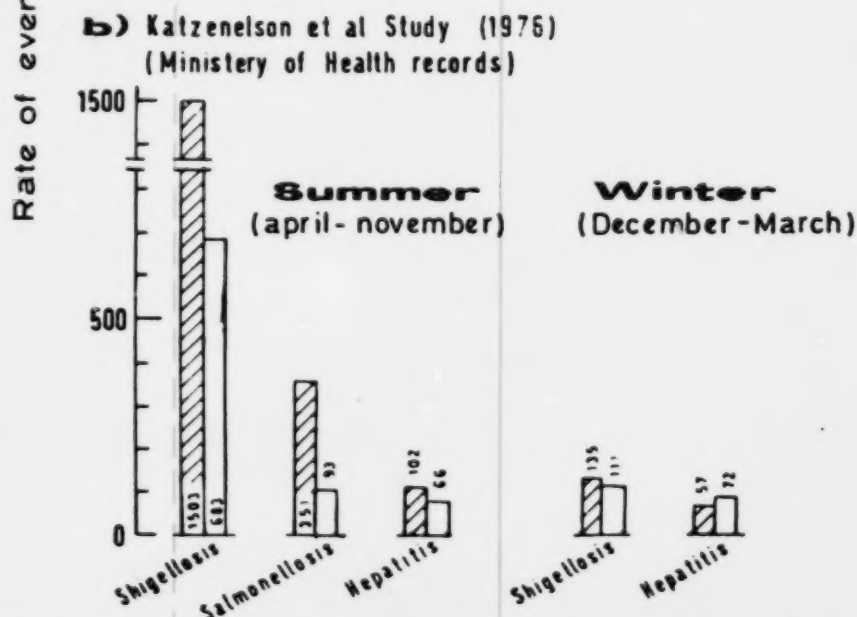
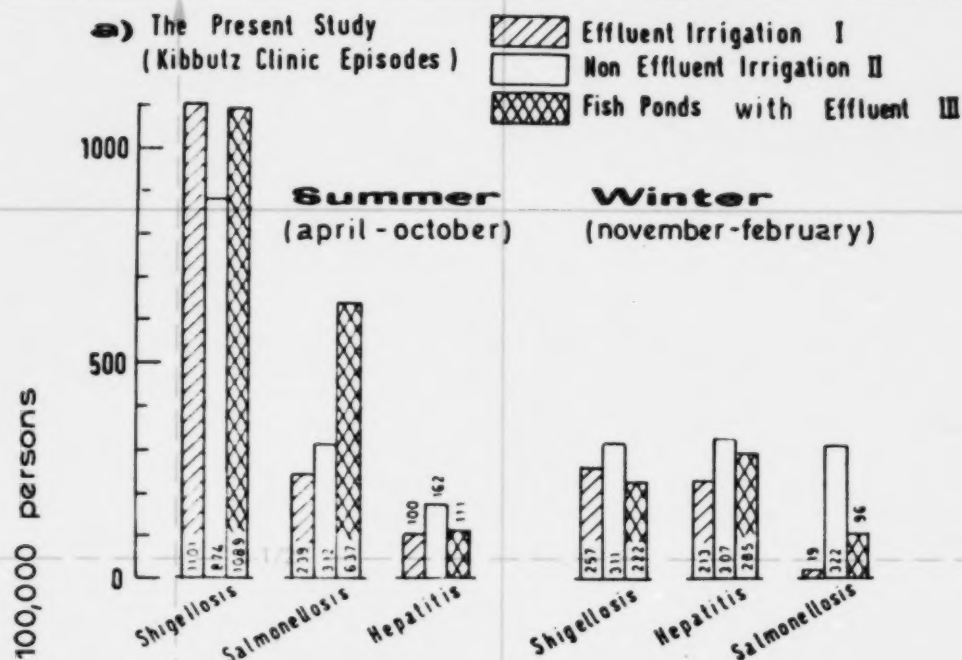


Figure 39. Comparison of rates of events/100,000 persons/year of shigellosis, salmonellosis and hepatitis in the present study and Katzenelson et al. study. (Figures in or outside of columns are rates of events/100,000 persons/year.)

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The present study did not confirm the findings of Katzenelson et al. (1976) of a major excess of specific enteric diseases in effluent irrigating kibbutzim vs. controls either during the irrigation season or on an annual basis.

LOGISTIC AND LOG LINEAR MODEL ANALYSIS FOR THE 68 KIBBUTZIM

The Validity of the Model's Assumptions

The log linear model assumes that the first two moments of the distribution of the number of enteric diseases for individuals in age group j during period i of calendar year k in kibbutz l which uses wastewater utilization method m are given by:

$$E[E_{sijklm}] = T_{il} \mu_{ijklm}, \text{Var} [E_{sijklm}] = \sigma_j^2 T_{il} \mu_{ijklm}$$

The logistic model assumes that the number of enteric diseases for each individual in a given time period is characterized by a different Poisson distribution. In contrast to the log linear model where no assumptions are made on the distribution of the number of control diseases, the logistic model further assumes the latter follows also a Poisson distribution. The two Poisson distributions share a common parameter which represents the individual reporting index. More formally the assumptions are:

$$\begin{aligned} \text{Independent } E_{sijklm} &\sim \text{Poisson} (T_{il} \cdot \delta_{sijklm} \cdot \theta_{ijklm}^E) \\ C_{sijklm} &\sim \text{Poisson} (T_{il} \cdot \delta_{sijklm} \cdot \theta_{ijklm}^C) \end{aligned}$$

A sufficient condition for the validity of the two models is thus:

$$\begin{aligned} \text{Independent } E_{sijklm} &\sim \text{Poisson} (T_{il} \cdot \theta_{ijklm}^E) \\ C_{sijklm} &\sim \text{Poisson} (T_{il} \cdot \theta_{sijklm}^C) \end{aligned}$$

The Poisson hypothesis is tested by the Dispersion test (Cox and Lewis, 1966). The test compares the ratio of the estimated variance to the estimated mean, to unity.

The test for goodness of fit was applied in full detail to data based on each of the calendar years. Further tests, in somewhat less detail, were performed for summer and winter seasons and for irrigation and non-irrigation periods separately. The latter calculations are not presented here.

Denote by $\bar{E}_{jk1}$ and S_{jk1}^2 the mean and variance of the number of enteric diseases for N_{jk1} individuals of age group j in kibbutz l during calendar year k . The Dispersion test statistic is equal to

$$d = (S_{jk1}^2 / \bar{E}_{jk1})(N_{jk1} - 1)$$

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The statistic is approximately distributed as χ^2 with $N_{jk}-1$ degrees of freedom under the Poisson hypothesis.

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Summary statistics (the mean and standard deviation) for the ratio of the estimated variance to the estimated mean of the number of enteric and control diseases in each age group population of the 68 kibbutzim during the four years of the study are given in Table 14. The ratios and their summary statistics show that:

- (I) The ratios, especially those for enteric diseases, are not much greater than one in many of the populations considered.
- (II) The distribution of the ratio in each age group does not vary much between the calendar years.
- (III) The coefficient of variation for enteric diseases is larger than the corresponding coefficient for control diseases.
- (IV) The ratios for the 5-17 age group tend to be smaller than the ratios for the 0-4 and 18+ age groups.
- (V) The 10 percent quintile of the ratio distribution for enteric diseases among the age group with the largest coefficient of variation, 0-4, is 0.85 while the 90 percent quintile is 1.75.

The Dispersion test rejects, however, the hypothesis that enteric and control diseases follow a Poisson distribution in most of the population considered. It should be noted, however, that with relatively large sample sizes as in this study, any conventional test of fit will be close to significant at traditional level even though the ratio of the variance to the mean is not much larger than one.

The range of the ratios for the yearly period and the fact that the ratios are much closer to one when short periods like irrigation, non-irrigation, summer and winter are examined, suggest that the Poisson distribution is a crude approximation of the distribution of the number of enteric clinical visits although the above distribution would probably be better approximated by a Negative Binomial distribution which is characterized by a variance to mean ratio greater than one.

The Poisson distribution is not, however, part of the Log Linear Model's assumptions. The model's main assumption is that the ratio of variance to the mean is constant within each age group. The spread between quintiles of the ratio distribution indicate that such an assumption is partly supported by the data.

These results imply that:

1. Several of the distributional assumptions which underly the log linear model are to any practical purpose satisfied by the data.

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TABLE 14. THE MEAN AND STANDARD DEVIATION OF THE RATIO OF ESTIMATED VARIANCE TO THE ESTIMATED MEAN OF THE NUMBER OF ENTERIC AND CONTROL DISEASES IN THE AGE GROUP POPULATIONS OF THE 68 KIBBUTZIM DURING THE FOUR YEARS OF THE STUDY

Calendar Year	Age Group		0-4		5-17		18+		All Ages	
			Enteric	Control	Enteric	Control	Enteric	Control	Enteric	Control
1974			1.27 (.74)*	1.66 (.80)	1.09 (.48)	1.34 (.42)	1.23 (.46)	1.44 (.35)	1.43 (.43)	1.77 (.61)
1975			1.28 (.55)	1.47 (.69)	1.06 (.37)	1.38 (.49)	1.28 (.37)	1.46 (.31)	1.42 (.34)	1.70 (.43)
1976			1.38 (.65)	1.52 (.69)	1.14 (.39)	1.33 (.41)	1.20 (.36)	1.51 (.49)	1.44 (.43)	1.75 (.50)
1977			1.28 (.49)	1.60 (.75)	1.12 (.34)	1.29 (.32)	1.18 (.31)	1.50 (.40)	1.37 (.31)	1.74 (.43)

* () Standard deviation

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2. The weighted least squares method provides a good working method for estimating the log linear model's parameters. This follows Cochran's (1980) experience with count data "which appeared at first sight to be Poisson but turned out to have extraneous variation as revealed by χ^2 test".
3. The Poisson assumption which underlies the logistic model seems to be more appropriate when the short periods (irrigation - non-irrigation, summer-winter) are considered.
4. The annual number of control diseases for individuals of the same age group in a kibbutz do not follow the same Poisson distribution. This does not indicate that the logistic model's assumptions are not satisfied since the latter allows for individual difference in the Poisson parameter. It suggests, however, that the log linear model may be more appropriate for the analysis of annual diseases rates.

The logistic model assumes also that the number of enteric and control diseases for an individual are independent. To test the validity of that assumption we computed the correlation between the number of enteric diseases and the number of control diseases for individuals in the three age groups during each year of the study. The resultant correlation varies between .17 to .27 with a mean around .23. During shorter periods, such as irrigation and non-irrigation and summer and winter these correlations are expected to be even smaller. The magnitude of these correlations show that the independence assumption made is indeed a crude approximation to reality.

The Goodness of Fit of the Models

The goodness of fit of the log linear model to the data is measured by the coefficient of determination (R^2) of the log of enteric diseases rate on the explanatory variables considered. The value of R^2 can be viewed as a measure for the proportional decrease in the predictive error of the log of enteric diseases rate that can be attributed to the explanatory variables considered.

An analogue goodness of fit statistic for the logistic model (Efron, 1978) is

$$ER = \frac{\log L_0 - \log L(\text{model})}{\log L_0}$$

where $\log L(\text{model})$ is the log likelihood of the estimated model and $\log L_0$ is the maximized log likelihood under the assumption that the log odds of enteric diseases does not depend on the values of the explanatory variables.

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The log likelihood function is sensitive to small changes in the likelihood value. As a result one observes low values for ER even for models which are highly suitable.

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The values of R^2 and ER for models which have been fitted to irrigation - non-irrigation, summer-winter, summer and winter alone, and annual diseases rates, together with the number of degrees of freedom (number of distinct covariate patterns - number of parameters in the fitted model) associated with each fitted model, are presented in Table 15.

Table 15 shows that the log linear model reduces the predictive error much more than the logistic model. It should be noted, however, that the observed difference in the goodness of fit of the two models is due not only to the noted property of ER but also to a major difference between the models. The log linear model controls for the difference in the quality of reporting by including in the model as a proxy the rate of control diseases. This factor, which has been found to be the most important explanatory variable in all analysis, is not included in the logistic model. The latter model considers instead the ratio of enteric to control diseases and relates it to the risk and confounding factors considered. Both models show therefore that when the difference in the quality of reporting is controlled for in this manner, the other risk and confounding factors do not seriously reduce the predictive error of enteric diseases rates.

Table 15 further indicates that models applied to both irrigation and non-irrigation periods fit the data better than the models which have been applied to either the summer, the winter, or the annual diseases rates. The table also shows that both models fit better the diseases rates for age group 5-17 and 18+ than those of age group 0-4. The fit of the logistic model to the annual disease rates is especially poor among age group 18+ and the total population.

It should be stressed, however, that the reduction in predictive error is strongly significant in each study. The same pattern is observed when the logistic model predicting power (to enteric and control diseases) is examined.

The classification tables (for enteric and control diseases) associated with the logistic model estimates of the conditional probability of enteric diseases show that the probability of misclassification ranges, for example, between 33 percent on the average for both enteric and control diseases when summer-winter diseases rates for age group 5-17 are analyzed, to 44 percent on the average when the annual diseases rates are considered.

It should be noted, however, that the goodness of fit of the logistic model cannot be tested through the various X^2 statistics since "these tests are not acceptable when the cells contain many small or zero counts" (Engelman, 1980)--a phenomenon typical of this study, where many of the numerous covariate patterns contain few enteric and control clinical visits.

The Risk Associated with Wastewater Utilization in the 68 Kibbutzim as Estimated by the Log Linear and Logistic Models

Table 16 presents the logistic model estimate of the odds ratio (OR) and the log linear model estimate for the relative risk (RR) of enteric diseases

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TABLE 15. THE SQUARED MULTIPLE CORRELATION COEFFICIENT (R²) FOR THE LOG LINEAR MODEL AND THE PROPORTIONAL REDUCTION IN THE PREDICTIVE ERROR (ER) FOR THE LOGISTIC MODEL

Age Group (Year)	Irrigation - Non-Irrigation Disease Rates		Summer (Irrigation) - Winter (Non-Irrigation) Disease Rates		Summer Disease Rates		Winter Disease Rates		Annual Disease Rates	
	R ²	ER	R ²	ER	R ²	ER	R ²	ER	R ²	ER
0-4	.43	.029	.47	.064	.38	.027	.38	.026	.46	.013
5-17	.56	.037	.57	.089	.48	.049	.46	.031	.50	.027
18+	.54	.028	.67	.071	.43	.021	.50	.023	.52	.007
All Ages	.58	.028	.65	.060	.52	.015	.49	.016	.59	.006

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for effluent kibbutzim (I) and kibbutzim using effluent as feed water for fish ponds (III) vs. non-effluent utilizing kibbutzim (II).

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The estimates of the OR and RR are presented side by side for purposes of convenient comparison. The analysis is for the age groups 0-4, 5-17, 18+ and all ages. The disease rates during four different time periods were examined. The first was the actual irrigation period and non-irrigation period for each individual kibbutz as based on the data obtained in the environmental survey. The mean number of months of irrigation for I was 8.1 and for II and III were 7.2. The second time period examined was the four month summer period of May-August and the four-month winter period of November-February for all 68 kibbutzim regardless of actual irrigation period. The third analysis was also for the four-month summer and four-month winter periods as above, but excluded those kibbutzim irrigating during the winter months of November through February. The fourth approach was to compare the enteric disease rates for the full 12 month annual period.

Effluent Irrigation vs. Non-Effluent Irrigation--

Table 16 shows that during the irrigation period effluent irrigating kibbutzim (I) have both a significantly higher odds ratio and relative risk than non-effluent irrigating kibbutzim (II) in each of the three age groups and all ages combined, excepting 0-4 and 5-17 where the relative risk is greater in I than II but the level of significance was only $P = 0.1$. In general, the increased risk during the irrigation period for all ages for enteric disease in effluent irrigating kibbutzim was about 1.8 times that of non-effluent irrigating kibbutzim as measured by the odds ratio and 1.4 times as measured by the relative risk.

During the non-irrigation period no consistent pattern can be discerned for the odds ratio except for all ages which was significantly lower in I than II. The relative risks for 18+ and all ages are also significantly lower in I than II. These findings suggest that during the non-irrigation period the enteric disease rates in I tend to be lower than II.

In the logistic and log linear models an adjustment was made for length of irrigation period. The length of irrigation period was found to be negatively correlated with enteric disease rates in general. For category I the "length of irrigation" coefficient was more negative than in II. As stated above, the mean length of irrigation period for I was greater than II thus enteric disease rates adjusted for length of irrigation period both by the log linear and logistic models tended to increase in I over II. This adjustment was naturally not applied to the analysis for fixed time periods such as summer vs. winter or annual.

Contrary to the findings for the irrigation period above, during the summer months (all kibbutzim) no significant pattern is apparent although in general the odds ratios and relative risks are not far from 1 implying no excess risk in I over II. As for the winter, there is a significantly lower risk of enteric disease in I over II by OR in all age groups. The RR follows the same trend but is not significant.

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TABLE 16. THE LOGISTIC AND LOG LINEAR MODEL ESTIMATES FOR THE ODDS RATIO (OR) AND RELATIVE RISK (RR) FOR 68 KIBBUTZIM WITH EFFLUENT IRRIGATION, NON-EFFLUENT IRRIGATION AND EFFLUENT ENRICHMENT OF FISH PONDS

Age Group	Comparison	ALL KIBBUTZIM					EXCLUDING KIBBUTZIM IRRIGATING IN WINTER					ANNUAL	
		ALL KIBBUTZIM					EXCLUDING KIBBUTZIM IRRIGATING IN WINTER					Annual	
		Irrig. Period (OR)	Non-Irrig. Period (OR)	Summer May - Aug. (RR)	Winter Nov. - Feb. (RR)		Summer May - Aug. (RR)	Winter Nov. - Feb. (RR)				(OR)	(RR)
0-4	Eff. vs. Non-Eff.	1.67 ^a	1.15	1.01	1.11	.91 ^b	.63 ^a	.72 ^a	.73 ^a	1.02	.77 ^a	.94	.85 ^a
	Fish Ponds vs. Non-Eff.	1.08	1.04	1.25 ^a	1.67 ^a	1.48 ^a	1.20 ^a	.99	.62 ^a	.83 ^a	.70 ^a	1.16 ^a	.76 ^a
	Eff. vs. Fish Ponds	1.54 ^a	1.10	.31 ^a	.60 ^b	.75 ^a	.76 ^a	.73 ^a	1.16	1.23 ^a	1.09	.81 ^a	1.12 ^b
5-17	Eff. vs. Non-Eff.	1.49 ^a	1.17	1.32	.84	1.09	.93	.81	.83 ^b	1.00	.73 ^a	.98	1.00
	Fish Ponds vs. Non-Eff.	1.98 ^a	1.31 ^b	1.97 ^a	1.92 ^a	1.34 ^b	1.11	1.26	1.07	1.00	.81 ^b	1.21 ^a	1.21 ^a
	Eff. vs. Fish Ponds	.75 ^a	.89 ^b	.67 ^a	.44 ^a	.81 ^b	.84 ^b	.64 ^a	.77 ^a	1.00	1.28 ^b	.81 ^a	.85 ^a
18+	Eff. vs. Non-Eff.	1.68 ^a	1.62 ^a	.45	.59 ^a	.84	.88	.53 ^a	.77 ^a	1.00	.94	.79 ^a	.92
	Fish Ponds vs. Non-Eff.	1.26	1.02	2.04 ^a	2.13 ^a	.80	.86 ^a	.56 ^a	.72 ^a	1.00	1.08	.62 ^a	.88
	Eff. vs. Fish Ponds	1.33	1.59 ^a	.22 ^a	.28 ^a	1.05	1.02	.95	1.07	1.00	.87	1.28	1.04
All Ages	Eff. vs. Non-Eff.	1.76 ^a	1.39 ^a	.73 ^a	.73 ^a	.92	.90	.58 ^a	.73 ^a	.94	.98	.87 ^a	.94
	Fish Ponds vs. Non-Eff.	1.50 ^a	1.84 ^a	1.87 ^a	1.87 ^a	1.21	1.06	.93	.92	1.02	.92	.82 ^a	.92
	Eff. vs. Fish Ponds	1.17	.75	.39 ^a	.39 ^a	.76	.85	.62 ^a	.79 ^b	.92	1.06	.89	1.02

^a - significance at 1 percent

^b - significance at 5 percent

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When winter irrigating kibbutzim are excluded, there was no consistent pattern during the summer months by OR; while by RR it appears that the risk of enteric disease in I is slightly lower than II but this trend is not significant except in the 0-4 age group. During the winter period, the risk of enteric disease is consistently and significantly lower in I than II except for 5-17 by OR. In general, the findings of the lower enteric disease risk in I over II in winter is supportive of the similar finding during the "non-irrigation" period.

On an annual basis there is clearly no significant excess risk in effluent irrigating kibbutzim (I) over non-effluent irrigating kibbutzim (II). In the 0-4 age group the risk by odds ratio was lower for I over II.

The fact that almost identical risk patterns result from both the log linear model and the logistic model for the "irrigation" and "non-irrigation" period adds weight to the suggestion that effluent irrigating kibbutzim have an added risk of enteric disease during the irrigation period and a reduced risk during the non-irrigation period. The two models are based on somewhat different assumptions and the results are obtained through different estimation techniques. It was felt that the congruence of the findings using two different methods suggests a real difference.

These findings are, however, in conflict with the risks for the somewhat comparable summer and winter seasons and must lead to a rejection of any clear conclusion suggesting an excess risk of enteric disease in effluent irrigating kibbutzim (I) during irrigation or summer periods in the study of the 68 kibbutzim.

It must be pointed out that there was no significant excess of risk in effluent irrigating (I) over non-effluent irrigating kibbutzim (II) on an annual basis. Thus from an over all public health point of view, even if the excess risk during effluent irrigation period was accepted, it appears that the population in effluent irrigating kibbutzim would have no over-all added risk of becoming ill with enteric disease in any given year than those residing in non-effluent utilizing communities.

Effluent Irrigating vs. Fish Ponds Enriched with Effluent--

In general the picture seen for I vs. III is somewhat akin to I vs. II, but even less clear cut and with essentially the same conflicting findings and anomalies. Thus, here too it is not possible to draw any concrete conclusion as to difference in enteric disease risk.

Effluent in Fish Ponds vs. Non-effluent Utilizing--

As for kibbutzim using effluent as feed water for fish ponds (III) they too were analyzed based on the same four time periods as used for effluent (I) and non-effluent (II) irrigating kibbutzim. However, it should be noted that the irrigation period for category III was based on irrigation with clean water as normally practiced in such kibbutzim and in no way related to the real periods of exposure to wastewater in III since fish ponds practice the use of wastewater effluent as feed water for essentially 12 months a

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year, regardless of irrigation period. The use of irrigation and non-irrigation periods for III, while not directly related to real periods of exposure to effluent, was used as a basis for comparing disease rates with category I.

From Table 16 it can be seen that there is a significant excess risk of enteric disease for III over II both by odds ratio and relative risk for all ages in both the irrigation and non-irrigation period. This significant excess appeared in each age category separately for the non-irrigation period, but during the irrigation period the excess is not significant in the 0-4 and 18+ age groups.

The consistent pattern of excess risk in III over II is not observed during the four summer or four winter months, except for an excess in III over II by RR in the winter in 0-4 and 5-17 when all kibbutzim are analysed. The summer-winter results are not supportive of the clearly significant excess risk of enteric disease found in III over II both in the irrigation and non-irrigation periods.

On an annual basis there was a significant excess in III over II in 0-4 and 5-17 by RR. All other findings point in general to the lack of any significant differences in enteric disease risks between III and II, with less risk in III than II for 18+ by OR.

On first thought, the finding by OR and RR of an excess of enteric disease rates in III over II in both irrigation and non-irrigation periods, but not on an annual basis (which combines both of the above seasonal periods) brings to mind the Simpson Paradox, which deals with possible exceptions to the "sure things principle" (Blyth, 1972). However, the Simpson Paradox has been used to explain such anomalies when they appeared in crude rates. In this case, the crude rates do show an excess of enteric disease in III over II in both irrigation and non-irrigation periods and on an annual basis. Whether or not an extension or modification of the Simpson Paradox would apply to our regression type model was not clear, among other reasons, since the annual data did not adjust for one of the covariates, namely the length of irrigation period.

The validity and goodness of fit of the logistic and log linear models was higher for "irrigation" and "non-irrigation" periods than for the "annual" rates. This was particularly true for the logistic model, which also appears to have an especially poor fit for 18+ and "all ages." Thus, more weight should be given to the findings of a significant excess in III over II on an annual basis in the "0-4" and "5-17" age groups as estimated from the log linear model. Despite the lack of a consistent picture, the weight of evidence does indicate an overall excess risk of enteric disease in kibbutzim utilizing wastewater in fishponds (III), over controls in both irrigation and non-irrigation periods and on an annual basis, at least in the 0-17 age groups.

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There was also evidence indicating that this excess risk applies to "all ages". However, the apparent conflicting findings emphasize the need for caution in interpreting these results.

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It should be stressed that the lack of consistency between the results of the irrigation - non-irrigation study and the summer-winter study, and the lack of significant results in the annual data cannot be attributed to Multicollinearity--strong linear relationship between the model's explanatory variables and its known effect--inflating the variances of the estimates to some parameters and as a result producing t-statistics which fail to reject the null hypothesis (Belsley, Kuh and Welsch, 1980, p. 106). This is so for the following reasons:

1. The strong colinearity between some of the explanatory variables in the irrigation - non-irrigation study is not harmful because the tests for the parameters of interest succeeded in rejecting the null hypothesis.
2. Multicollinearity among the annual data explanatory variables is not severed.
3. A harmful multicollinearity is also characterized by unstable regression coefficients which are highly sensitive to the estimation method employed. The strong similarity of the results from the weighted least squares estimation to the Log Linear Model, and the maximum likelihood estimation to the Logistic Model parameters, provides therefore another indication of the harmless effect of multicollinearity.

Factors Effecting Enteric Disease Risk

Table 17 shows the relative risk and odds ratio of those factors found to have a significant influence on enteric disease rates. Only those factors found to be significant ($p < 0.1$) by both OR and RR in all ages and at least two other age groups were included.

A factor of great influence on enteric disease rates was length of irrigation period. In general, with increase in length of irrigation period there was a decrease in enteric disease rates. For example, an effluent irrigating kibbutz with irrigation period of about 1 month more than its effluent irrigating neighbor kibbutz would thus be expected to have an enteric disease rate about 10 percent lower.

The northern region had higher enteric disease rates than the southern with the central region greater than both.

Effluent from local sources was found to be associated with higher enteric rates than non-local effluent.

As to sources of drinking water, higher enteric disease rates were found in kibbutzim recorded as receiving water from the national or regional water pipelines than from local mekorot or nearby wells. The reliability of the data on this point is open to question, since not all kibbutzim could provide accurate information as to water sources.

With increasing population size there appears to be an increased risk of enteric disease in the 0-4 age group, but a decrease in all other age groups.

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TABLE 17. THE RELATIVE RISK AND ODDS RATIO OF ENTERIC DISEASES FOR FACTORS WHICH HAVE BEEN FOUND TO BE SIGNIFICANT ($P < 0.1$) IN BOTH THE LOGISTIC AND LOG LINEAR ANALYSIS

AGE GROUP (Year)	0-4				5-17				18+				ALL AGES			
	Logistic OR	Linear	Log RR		Logistic OR	Linear	Log RR		Logistic OR	Linear	Log RR		Logistic OR	Linear	Log RR	
Length of Irrig. Period																
1 Month of Eff. Ir.	.90		.92		.91		.97		.91		.94		.90		.93	
1 Month of Non-Eff. Ir.	1.00		.95		.95		.99		.97		1.02		.98		.98	
Region of Kibbutz																
South vs. North	N.S.		N.S.		.72		.80		.42		.64		.58		.81	
Center vs. North	N.S.		N.S.		1.50		1.30		2.34		1.57		1.67		1.25	
Source of Sewage Ir.																
Source of Non-Sewage Irrigation																
Local vs. Non-Local	1.21		1.37		1.29		1.22		N.S.		N.S.		1.27		1.44	
Source of Drinking Water																
Mekorot - Local Well vs. National Pipeline	.62		.81		.53		.85		.89		.82		.64		.75	
Size of Population																
An increase by 100	1.53		-		.91		-		.92		-		.98		-	
Rate of Clinic Visits																
Increase by 1	.94		1.01		N.S.		1.05		.95		1.02		.94		1.03	
Log (Rate of Control Disease)																
An increase of 100 percent in the rate of control diseases	-		1.33		-		1.32		-		1.40		-		1.47	

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Increased control disease rates are highly associated with increased enteric disease rates. This may be associated with the quality of reporting effect.

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Another factor assumed to be associated with the quality of reporting was the rate of total clinic visits. Here, however, the results by OR and RR were conflicting and no clear patterns can be discerned.

SWITCH CATEGORY KIBBUTZIM (IV) - CRUDE RATES

General

For the switch category (IV), the design required that each kibbutz practice two consecutive years during which effluent sources were used for irrigation for at least part of the year. These were called the "effluent years". The other two consecutive years, during which only non-effluent sources of water were used for irrigation, were called the "non-effluent years" (total of 11 kibbutzim).

For six kibbutzim with a population of 1652, the sequence was 2 non-effluent years followed by 2 effluent years and vice versa for five kibbutzim with a population of 1388, with a total population of 3040. The range of population in the kibbutzim was 146-378 persons.

The age distribution in category IV was as follows: 0-4, 13.4 percent; 5-18, 28.1 percent; 19+, 58.5 percent. By inspection, no differences in the age distribution by sex were observed. The mean number of irrigation months was 7.8, ranging from 4-12 months, with most kibbutzim irrigating between April through September, and all irrigating at least during the months of June through August.

For the two effluent years, we defined the effluent irrigation period for each year as the months during which effluent was utilized. For the two non-effluent years, we defined the non-effluent irrigation period as the parallel months.

Of the 17 kibbutzim which were potential candidates for the switch category, six had to be dropped from the analysis due to lack of data, or other technical problems.

Part of the data analysis of category IV preceded that of the remaining 68 kibbutzim and was to some extent a pilot stage. Thus the procedures in this analysis were at times somewhat different than those used in the analysis of the 68 kibbutzim.

The crude disease rates used in this section are for clinic visits/1000 persons/year for the two major disease categories, total enteric diseases and total control diseases as presented in Table 1. Population was established for each kibbutz and age group by a count of the clinic file and was used as the mean for the total 4-year period. In the logistic model, the ratio of enteric disease over control disease was used, as explained later on. The rate of enteric disease/1000 persons per year based on clinic visits was used in the log linear model.

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Comparison of Crude Disease Rates

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Figure 40 shows the crude rates for enteric and control diseases during the irrigation period in the group with the sequence of non-effluent years followed by effluent years, separately from the reverse sequence, by various age groups. There was an observed large excess of enteric disease (Figure 40a) during the effluent years in the non-effluent to effluent sequence, which does not appear as strong in the reverse sequence. There was also an apparent excess of total control disease (Figure 40b) during the irrigation period in that same sequence.

Figure 41 shows the rates for enteric and control diseases during the effluent and non-effluent years; irrigation and non-irrigation periods were combined. The histogram was set up for each kibbutz, for the sequences of non-effluent to effluent years and vice versa, each separately. There was an observed excess of enteric disease in five kibbutzim out of six during the non-effluent to effluent years sequence, while one showed a decrease for the same sequence. For the sequence effluent to non-effluent, two kibbutzim showed an excess during the effluent years, and a decrease in the remaining three. There was also an apparent excess in total control diseases in five kibbutzim out of six in the non-effluent to effluent sequence, and a decrease in one. In the control group effluent to non-effluent years sequence, only three out of five kibbutzim showed an apparent excess; two kibbutzim showed a decrease.

Figure 42 shows the rate of enteric and control diseases during the entire year (irrigation and non-irrigation periods combined), in two age groups, 0-4 years and all ages, in the sequence non-effluent to effluent years, and in the reverse sequence. It can be seen that there was an excess in enteric disease rates in each age group in the non-effluent to effluent sequence only. There was also an apparent excess in control diseases mainly in the sequence non-effluent to effluent.

LOGISTIC AND LOG LINEAR MODEL ANALYSIS FOR THE SWITCH CATEGORY

Validity and Fit of Models

The values of the coefficient of determination ($R^2 = .93, .95$) for the fit of the log linear model to the irrigation period and annual diseases rates respectively indicate that both models fit the irrigation period and the annual data particularly well. The corresponding values of the predictive error reduction ($ER = .15, .10$) for the logistic model show a similarly good fit to the data. When the logistic model was applied to classify the type of each disease (enteric or control) for each distinct pattern of covariate variables it succeeded in about 70 percent of both types of diseases. The far superior fit obtained in this study as compared to that observed in the 68 kibbutzim study was due to its complete block type design which by its very nature overcomes many of the complex confounding factors found in the study of the 68 kibbutzim.

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Another advantage of the switch category design is that data for four consecutive periods in the 11 kibbutzim covered different years ranging from

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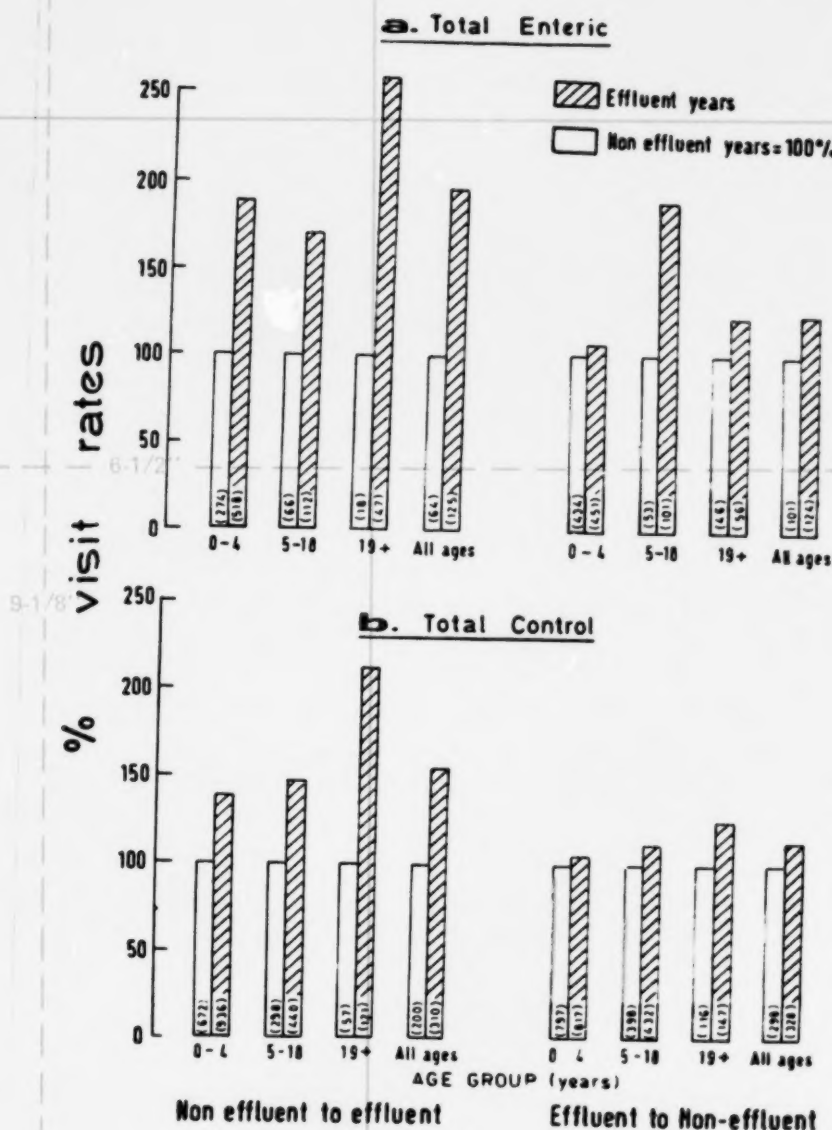


Figure 40. Comparison of the visit rates of total enteric and total control diseases in the switch category during irrigation period with the sequence non-effluent to effluent years and vice versa by age groups. (Figures in columns are rates of visits/1000 persons/year.)

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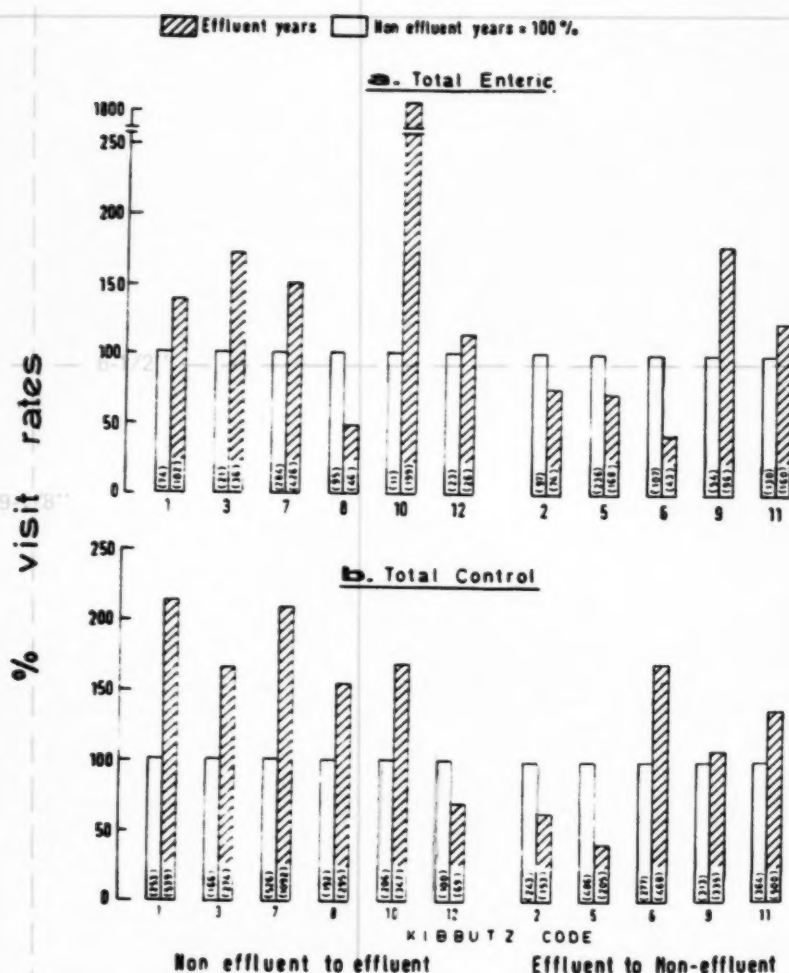


Figure 41. Comparison of the visit rates of total enteric and total control diseases in the switch category during the effluent and non-effluent years by each kibbutz separately for all ages. Irrigation and non-irrigation periods combined. (Figures in columns are rates of visits/1000 persons/year.)

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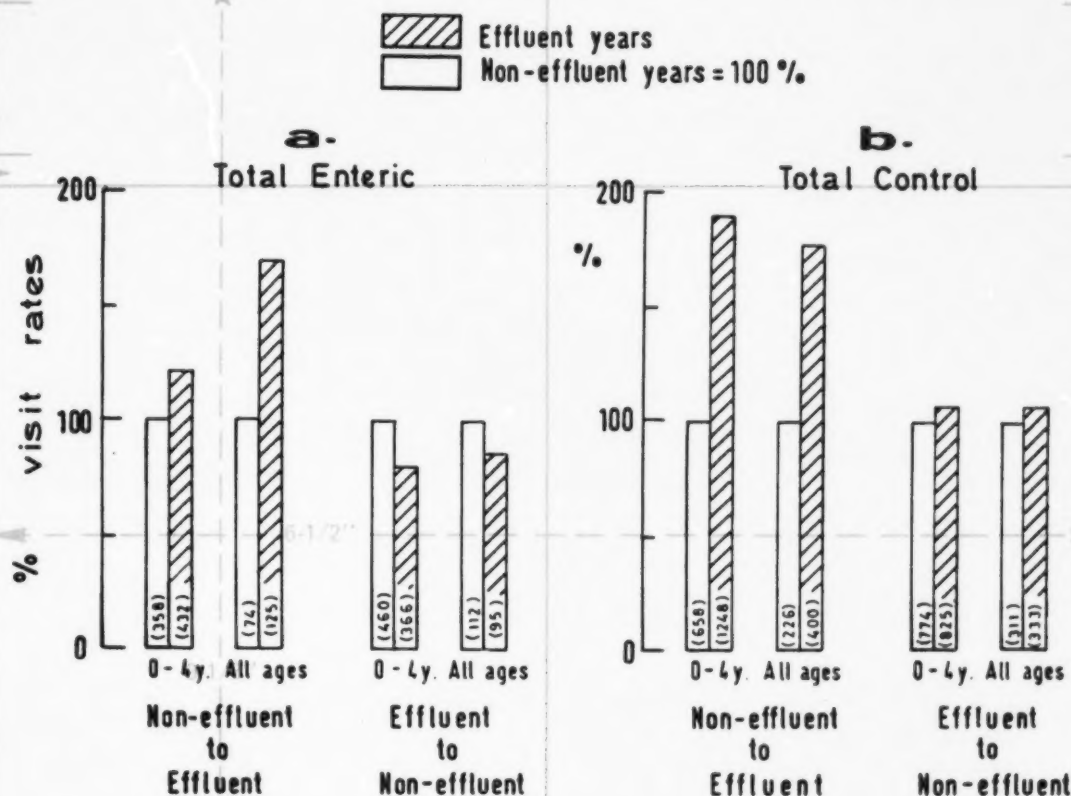


Figure 42. Comparison of the visit rates of total enteric and total control diseases in the switch category during effluent and non-effluent years for 0-4 and all ages. Irrigation and non-irrigation periods combined. (Figures in columns are rates of visits/1000 persons/year.)

1963 to 1976. This reduced to some extent possible confounding effects associated with national or regional epidemic cycles. This is of particular importance in a retrospective study of this kind where it was not possible to control for epidemic events in the individual kibbutzim which may bias the disease rates.

The advantages of the design of the switch category overcome many of the disadvantages that might be associated with the small number of kibbutzim and the corresponding relatively small (55) number of degrees of freedom for estimating the models' parameters.

In both the logistic and log linear analyses of the kibbutzim in the switch category, a significant difference between kibbutzim was found for the "effect of the kibbutz" on the risk of enteric disease ($P < 0.01$).

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These differences were found in each of the two switch groups, i.e., from effluent to non-effluent and non-effluent to effluent. The "effect of the kibbutz" may be related to such diverse factors as quality of reporting, effect of geographic region, or other real differences in enteric disease risks such as food hygiene, exposure to animal wastes, quality of drinking water, etc.

The significance of some of these kibbutz effects show the importance of adjusting for confounding factors in each kibbutz and indicate that the rate of enteric diseases and the ratio of enteric to control disease cannot be assumed to be constant in the two switch categories. This analysis also found significant interactions between the "kibbutz effect" in some kibbutzim and irrigation with effluent or non-effluent. This implies that the odds ratio and relative risks of enteric diseases for effluent vs. non-effluent irrigation cannot be assumed to be the same for all the kibbutzim in each of the switch categories. The importance of this fact will be discussed later when the Mantel-Haenszel (M-H) procedure is presented. The non-significance of the regression coefficient of the log of the control disease rate suggests that the quality of reporting in a kibbutz does not change significantly over the years.

Estimate of Risk of Enteric Disease

The logistic and log linear models' estimates for the odds ratios and relative risks of enteric diseases during irrigation period for effluent vs. non-effluent irrigation in each switch category is given in Table 18.

Table 18 shows that the odds ratio and relative risk of enteric diseases among 0-4 age group and the total population are greater during the effluent irrigation years in each of the two switch categories. The results are significant ($P < .01$) among 0-4 age group both by OR and RR for both forms of switch.

The results were also significant for 19+ and all ages by RR in the switch from non-effluent to effluent and in the 5-18 age group by OR in the effluent to non-effluent switch.

The finding of significant excess risk of enteric disease during effluent irrigation periods in the 0-4 age group in both types of switch of 1.7-2.12 by OR and 1.32-1.36 by RR is particularly strong. Part c of Table 18 combines part a and b disregarding direction of switch. Only in 0-4 was there a clearly significant excess of enteric disease during the irrigation period of 1.9 of OR and 1.34 for RR.

The hypothesis that effluent irrigation increases the risk of enteric diseases among the 0-4 age group can also be examined through the Mantel Haenszel (1959) procedure. The procedure considers the 2x2 table of disease (enteric, control) against type of water used for irrigation (effluent, non-effluent) for each kibbutz and computes the corresponding ratio of the odds of enteric diseases during effluent irrigation vs. the odds of enteric diseases during non-effluent irrigation periods. These odds ratios are then weighted to obtain a combined odds ratio. The significance of the

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TABLE 18. THE LOGISTIC AND LOG LINEAR MODEL ESTIMATES OF THE ODDS RATIO AND RELATIVE RISK OF ENTERIC DISEASES FOR EFFLUENT IRRIGATION YEARS VS. NON-EFFLUENT IRRIGATION YEARS DURING THE IRRIGATION PERIOD IN THE SWITCH CATEGORY

Form of Switch	Age Group (Year)	Logistic Odds Ratio (OR)	Log Linear Relative Risk (RR)
A. non-effluent to effluent	0-4	2.12a	1.32a
	5-18	.69	1.09
	19+	1.02	1.37b
	All Ages	1.23	1.25a
B. effluent to non-effluent	0-4	1.70a	1.36a
	5-18	1.65b	1.13
	19+	.63	.79
	All Ages	1.14	1.07
C. regardless of form of switch	0-4	1.90a	1.34a
	5-18	1.07	1.13
	19+	0.81	1.04
	All Ages	1.19	1.16

(a): a - significant at 1 percent
b - significant at 5 percent

combined odds ratio is tested through a χ^2 statistic with one degree of freedom.

The test is most suitable when the alternative postulates odds ratios which are constant across the kibbutzim. The validity of this assumption has been examined by the logistic model analysis. The analysis indicates that the odds ratios are in fact different across the kibbutzim in each of the switch categories. Since the Mantel-Haenszel (M-H) test is still valid and unbiased in this situation and the M-H estimate for the combined odds

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ratios has been shown (McKinaly, 1978) to be adequate in some cases where the odds ratio are not constant across strata, we applied it to the two switch categories. The results show that the logistic and log linear analysis (Table 18) and the M-H procedure (see Table 19) agree on the significance of the odds ratio in the category of the kibbutzim which switched from non-effluent to effluent ($P < .035$). The large difference between 1.7 (the logistic model estimate for the odds ratio in the kibbutzim which switched from effluent to non-effluent) and .90 (the M-H estimate for the same odds ratio) is due to one kibbutz. The odds ratio for that kibbutz was 0.38 while the odds ratio for all other kibbutzim in that category vary between 1.03 to 5.78. It must be remembered that the possibility of an epidemic in a kibbutz in one of the calendar years might invalidate the use of the M-H estimator. This result shows that the M-H estimation may provide a poor summary statistic when the odds ratio across stata are statistically different.

The logistic and log linear models estimates for the odds ratios and relative risk of annual enteric diseases for effluent vs. non-effluent irrigation are given in Table 20.

Table 20 shows that the annual excess of risk of enteric diseases during effluent irrigation years among the three age groups is significant ($P < .01$) when estimated by the log linear relative risk but not significant when estimated by the logistic odds ratios.

While the results of the OR as estimated by the logistic model do not support the significant excess in annual enteric disease rates as found in the RR as estimated by the log linear model, they do not necessarily negate this finding which is significant in all three age groups and all ages combined. The annual excess of enteric disease in effluent irrigation years is about 10 percent.

TABLE 19. THE MANTEL-HAENSZEL (M-H) ESTIMATE FOR THE COMBINED ODDS RATIO AND TEST FOR THE EQUALITY OF THE ODDS OF ENTERIC DISEASES AMONG THE 0-4 AGE GROUP DURING EFFLUENT IRRIGATION TO THE CORRESPONDING ODDS DURING NON-EFFLUENT IRRIGATION PERIODS

Kibbutz Category	Odds Ratio By M-H	χ^2	P Value For One Side χ^2 Test
Switched from non-effluent to effluent	1.47	3.27	.035
Switched from effluent to non-effluent	.90	.29	.39
All kibbutzim	1.10	.45	.33

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TABLE 20. THE LOGISTIC MODEL ESTIMATE FOR ODDS RATIO (OR) AND LOG LINEAR MODEL ESTIMATE OF RELATIVE RISK (RR) OF ANNUAL ENTERIC DISEASE FOR EFFLUENT VS. NON-EFFLUENT IRRIGATION

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Age Group (Year)	Logistic (O.R.)	Log linear (R.R.)
0-4	.91	1.11a
5-18	.91	1.10a
19+	1.18	1.11a
All Ages	.98	1.11a

a - Significant at 1 Percent.

The rates and odds of enteric diseases have been shown to be unequal among the kibbutzim in each of the switch categories. To study the relationship between those odds and the size of effluent irrigated field, and the distance between the effluent irrigated field and the kibbutz dining room, we plotted the estimated kibbutz effects against the corresponding values of each of these two variables. The scattergrams show that the difference in the proportion of enteric disease among the kibbutzim are not related to the two variables.

In conclusion, the analysis of the switch category points to a clear and significant excess of enteric disease in the 0-4 age group during effluent irrigation periods regardless of the nature of the switch. A significant excess risk of enteric disease during effluent irrigation periods is also found in other age groups, but is somewhat less clear cut. There is also a strong suggestion that there is an excess of enteric disease on an annual basis during effluent irrigating years regardless of the nature of the switch.

Because of the advantageous nature of the experimental design of the switch category and the particularly good fit of both the logistic and log linear models to the data set, it is felt that the above conclusions have a sound basis. They provide reasonably good evidence that there is indeed a clear and significant excess of risk of contracting enteric diseases during effluent irrigation periods, particularly in the 0-4 age group. There is also evidence of a small, but significant, excess risk of enteric disease on an annual basis in those kibbutzim utilizing effluent for irrigation vs. those irrigating with non-effluent. Although the findings for the 68 kibbutzim are conflicting and fraught with anomalies, the suggested excess risk of enteric disease during the "irrigation period" found there does find support in the results of the switch category.

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Figure A-1, Personal Medical Record

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ENVIRONMENTAL HEALTH LABORATORY המעבדה לבריאות הסביבה Nadassah Medical School P.O. Box 1172 Jerusalem, Israel					
PERSONAL MEDICAL RECORD					
Date: תאריך מילוי השאלון		Name of patient: שם החולה:			
kibbutz recording code		nurse identification		sex	
1-4		5-9		1: m 2: f 0: unknown	
Sup		year of 1st visit to clinic		total no. visits recorded during surveyed period	
		14-15		16-17	
				18	
				type of population	
				1.members 2.on probation 3.children 4.ulpan for new immigrants 5.temporary,volun- 6.soldiers 7.others 0.not known	
9-1/8 Name of Patient שם המחלה		code of disease/day /month/year		Date of Visit	
1				1ab. test	
2				19 - 26	
3				27 - 34	
4				35 - 42	
5				43 - 50	
6				51 - 58	
7				59 - 66	
8				67 - 74	
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				1.not tested 2.positive result 3.negative result 0.not known	

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Figure A-2, Environmental Questionnaire

Hebrew University-Hadassah Medical School

Jerusalem

Environmental Health Laboratory

QUESTIONNAIRE

Environmental Pollution in Kibbutzim

In Connection with Enteric Communicable Diseases

1. General:

- 1.1. Date _____ 1.2. Time of beginning of interview _____ 1.3. Time of conclusion _____
1.4. Name of Interviewer _____ 1.5. Name of Interviewee _____
1.6. Title of Interviewee _____ 1.7. Name of Kibbutz _____
1.8. Kibbutz Movement _____ 1.9. County _____
1.10. Administration District _____

2. Utilization of Sewage:

- 2.1. Does the kibbutz utilize sewage for irrigation today?
_____ yes, since _____ volume used (m^3 /year) _____
_____ no
2.1.1. If not, did you use it in the past?
_____ yes, from _____ (dates) Method of irrigation used _____
_____ no
2.1.2. If not, do you plan to use sewage in the future?
_____ yes, from _____ for the purposes of _____

3. Source of Sewage Used:

- 3.1. What are the sources of sewage that are used for irrigation?
_____ local (the kibbutz only) since _____
_____ local & other since _____
_____ other since _____

If using other resources, what are they? _____

4. Volumes of Sewage Used:

- 4.1. Volume used for irrigation _____ m^3 /year
4.2. Volume used for Fish ponds _____ m^3 /year
4.3. Total volume used _____ m^3 /year

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5. Method of Irrigation:

5.1. What were the methods of irrigation used?

☐ Flooding since _____
☐ Dripping since _____
☐ Furrowing since _____
☐ Spraying since _____

5.2. Type of sprinklers (catalogue #)

☐ cannon
☐ sector
☐ multiple use
☐ other (specify) _____

5.2.1. Sprinkler length (in meters) _____

5.2.2. Distance between sprinklers (in meters) _____

5.2.3. Distance between lines (in meters) _____

5.2.4. Pressure in the pipe (in Atmospheres) _____

6. Time of Irrigation:

6.1. Number of hours per day (on the average) _____ since _____

6.2. Time of day (most common) _____ since _____

6.3. Months of irrigation _____ since _____

7. Swimming Pool:

7.1. Does the kibbutz have a swimming pool?

☐ No (Skip to 7.7.)
☐ yes, since _____

7.2. Who swims in it?

☐ kibbutz members only
☐ kibbutz members and outsiders

7.3. Do you use any disinfectant methods or systems?

☐ yes kind of system _____ since _____
☐ no

7.4. Does the swimming pool have a filter system? ☐ yes ☐ no.

7.5. Is the pool connected to the sewage system?

☐ yes, since _____
☐ no

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7.6. Do you utilize the water from the pool for any other purposes?

☐ yes, for _____ since _____
☐ no

7.7. Is there any other swimming pool for children?

☐ yes age group _____ since _____
☐ no

7.8. If yes, do you use any disinfectant for it?

☐ yes type _____ since _____
☐ no

8. Fish ponds:

8.1. Does the kibbutz have fish ponds?

☐ yes, since _____
☐ no

8.2. Did it have in the past?

☐ yes, from _____
☐ no (skip to 9)

8.3. Is sewage used to fertilize the ponds?

☐ yes, since _____ volume (m^3 /year) _____
☐ no

8.4. Are chicken droppings used to fertilize the ponds?

☐ yes, since _____ amount (kg/year) _____
☐ no

8.5. Is cow manure used to fertilize the ponds?

☐ yes, since _____ amount (kg/year) _____
☐ no

8.6. Does the manure used undergo any sort of disinfection?

☐ yes method used _____ since _____
☐ no

9. Sewage Treatment Plant:

Does the kibbutz have a sewage treatment plant?

☐ yes type _____
☐ no Where does the sewage flow? _____

Details of Treatment Plant: _____

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10. Industry:

10.1. Is there any kind of industry in the kibbutz?

 yes kind since
 no

10.2. Is it connected to the kibbutz sewage system?

 yes
 no Where does the industry sewage flow?

11. Livestock:

11.1. Does the kibbutz have a barn?

 yes, since number of cows
 no

11.2. Is the barn connected to the sewage system?

 yes, since
 no

11.3. Does the kibbutz have chicken coops?

 yes, since How many
 no

11.4. Are the chicken coops connected to the sewage system?

 yes, since
 no

11.5. Does the kibbutz have a sheepfold?

 yes, since How many?
 no

11.6. Is the sheepfold connected to the sewage system?

 yes, since
 no

11.7. Is there a children's animal farm in the kibbutz?

 yes, since How many animals?
 no

11.8. Is the farm connected to the sewage system?

 yes, since
 no

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12. Crops: .

12.1. Which major crops grow in your kibbutz?

plantations since _____ no. of hectares: _____

grass _____ since _____ no. of hectares: _____

pastures	since	no. of hectares:
----------	-------	------------------

other (specify)	since	no. of hectares:

12.2. Which of the above are irrigated with sewage?

plantations	since	no. of hectares:

grass since "

pastures	since	"
----------	-------	---

other 6-1-2011 since "

13. Agricultural Products:

13.1. What is the major agricultural product of the kibbutz?

9-1/8" since

13.2. What is the major product? (agricultural or industrial)

since

13.3. Is any agricultural product used by the kibbutz?

yes since product

до

13.4.If yes, how is the product irrigated?

sewage	since	
--------	-------	--

other	since	
-------	-------	--

13.5. Where does the kibbutz acquire its milk supply?

From its own production mainly.

From outside the kibbutz mainly.

From its own production and outside the kibbutz.

14. Size of Lands and Areas:

14.1. Total area of the kibbutz:	hectares
----------------------------------	----------

14.2. Residential area: hectares

14.3. Size of sewage irrigated area: hectares

14.4. Fish ponds area with sewage:	hectares
------------------------------------	----------

14.5. Fish ponds area without sewage:	hectares
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15. Number of kibbutz residents:

	1	2	3
members			
children			
members in army service			
outside workers			
members on probation			
ulpan, (Hebrew studies living in the kibbutz)			
volunteers			
others			

16. Age and Sex of Residents:

16. Age/sex	M	F	M	F	M	F
0-4						
5-9						
10-14						
15-18						
19-24						
25-34						
35-44						
45-54						
55-69						
70+						

16.2. No. of persons working in chicken coop _____ in barn _____.

16.3. No. of persons working in irrigation _____.

16.4. No. of persons working in the fish ponds _____.

17. Sleeping Arrangements:

17.1. Do children aged 0-10 years remain with their parents at night?

yes, since _____

no

17.2. Do children aged 11-18 years remain with their parents at night?

yes, since _____

no

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18. Sources of Water

18.1. What is the source of drinking water?

____ National pipeline since _____
____ The Jordan River since _____
____ wells since _____
other(specify) _____ since _____

18.2. Total amount of water used: m³/year _____ since _____

18.3. Amount of water used for irrigation: m³/year _____ since _____

18.4. Amount of water used for fish ponds: m³/year _____ since _____

18.5. Amount of water used for industry: m³/year _____ since _____

18.6. Is the drinking water disinfected?

____ yes, since _____ method used _____
____ no _____ 6-1/2" _____

18.7. Does the kibbutz have any water reservoirs?

____ yes, since _____ Are they covered? _____
____ no _____

18.8. Bacteriological quality: _____

19. Climatology

19.1. Height above sea level _____

19.2. Amount of rains (mm/year) _____

19.3. Average temperature in winter (November-April) _____
in summer (May-October) _____

19.4. Average humidity in winter _____
in summer _____

19.5. Wind velocity _____

20. Distances:

20.1. Distance between Central Dining Room and nearest sewage irrigated field: _____

20.2. Distance between Central Dining Room and fish ponds: _____

20.3. Distance between Central Dining Room and cowsheds: _____

20.4. Distance between Central Dining Room and chicken coops: _____

20.5. Distance between Central Dining Room and the garbage collection center: _____

20.6. What does the kibbutz do with the garbage?

____ burn _____ bury other(specify) _____

General Remarks: _____

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